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DOSAG - I

Simulation Of Water Quality In Streams & Canals

Program Documentation
And
Users Manual

TEXAS WATER DEVELOPMENT BOARD

September 1970

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The report documents a mathematical model developed to predict the steady state dissolved oxygen concentrations in streams and canals resulting from a specified set of streamflow, wasteload, and temperature conditions. The model will determine the streamflow required to maintain a specified dissolved oxygen goal and will search the system for available storage to achieve the goal. The model can be used to estimate mean monthly dissolved oxygen levels over a full year. Both carbonaceous and nitrogenous oxygen demands are included and up to five degrees of treatment for both can be specified.

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Program Documentation

And

User's Manual

SIMULATION
OF
WATER QUALITY
IN
STREAMS AND CANALS
DOSAG-I

Prepared
By

Systems Engineering Division
Of The
Texas Water Development Board

September 1970

FOREWORD

DOSAG-I, documented herein, is one of two programs the Texas Water Development Board has for use in stream quality simulation studies. DOSAG-I is used to simulate the spatial and temporal variations in biochemical oxygen demand (B.O.D.) and dissolved oxygen concentration (D.O.) under various conditions of temperature and headwater flow. Its principal use is for rapid evaluation of a number of varying stream conditions.

The basic code for the DOSAG-I stream quality routing model was originally developed by the Federal Water Pollution Control Administration (now the Water Quality Office, Environmental Protection Agency) and was given to the Texas Water Development Board by that agency. The revised model is computationally the same as the original; several options have been added to increase its flexibility, and the input and output formats for the model have been completely revised to enhance its usefulness. A detailed description of the model and the changes are contained in this report.

The model has been extensively tested and should be essentially machine independent. A wide variety of stream conditions have been simulated and the model has performed well in each case. However, because of possible difficulties, it is recommended that the user of this program exercise due caution and not attempt to simulate conditions which are significantly different from those outlined in this report. If this recommendation is followed, DOSAG-I will prove to be an efficient and reliable tool for water management investigations.

The other program, QUAL-I, is described in a separate TWDB report. This model is more accurate and provides a more precise definition of the stream conditions than does DOSAG-I. QUAL-I is designed to simulate the spatial and temporal variations in water temperature and conservative mineral concentration as well as B.O.D./D.O. and is thus a more flexible model. These added features are obtained with a substantial increase in computational time. The two programs are designed to be used as complements to each other. DOSAG-I can provide the user with a rapid evaluation of a number of alternative conditions whereas QUAL-I permits a detailed analysis of the physical phenomena in the stream system.

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STREAM QUALITY ROUTING MODEL
DOSAG-I

PURPOSE

The purpose of this model is to calculate the biochemical oxygen demand and the minimum dissolved oxygen concentration in a particular stream system. If desired, the minimum dissolved oxygen concentration in the stream system may be checked against a pre-specified target level dissolved oxygen concentration. If the minimum dissolved oxygen level is below the target dissolved oxygen level, the program will compute the required amount of flow augmentation to bring the dissolved oxygen level up to the target level in the entire system. The user of the program specifies the locations within the stream system at which dilution water is available for flow augmentation. The program is designed to be run for varying climatic and hydrologic conditions during a twelve month period. Thus, it is possible to enter up to twelve different temperatures and corresponding discharges to each of the headwaters within the stream system being modeled.

The DOSAG-I model is quite flexible and can be adapted to any stream system. One major restriction is that large impoundments such as reservoirs cannot be considered by this program; the "state-of-the-art" of dissolved oxygen modeling has not yet progressed to the point where dissolved oxygen levels in reservoirs can be accurately predicted. The output from a single run of the DOSAG-I dissolved oxygen simulation model will provide the user with a complete description of the dissolved oxygen resources of the stream system investigated, and the required dilution water needed to bring the system up to the target level dissolved oxygen concentration. An additional user option available with this program is the ability to find the dissolved oxygen distributions for varying levels of treatment (waste treatment plants) in the simulated river basin.

RESTRICTIONS

(1) Maximum number of headwater stretches = 10.

(2) Maximum number of junctions = 20.

(3) Maximum number of reaches = 50.

(4) Maximum number of stretches = 20.

(5) Maximum of twelve months of routing for temperature and headwater flows; a minimum of one month must be used.

(6) Maximum number of dissolved oxygen targets = 4. A minimum of one dissolved oxygen target must be specified.

This dissolved oxygen target may be entered as a negative number if no flow augmentation is desired.

(7) Maximum of five degrees of treatment for both carbonaceous and nitrogenous wastes; a minimum of one degree of treatment may be specified. If the user does not wish for the degree of treatment calculations to be used in the modeling process, a number less than one should be entered as the treatment factor for both types of wastes.

SOLUTION TECHNIQUE

The DOSAG-I water quality simulation model solves for the biochemical oxygen demand and dissolved oxygen profiles in a stream system using conventional and accepted practices for the solution of this type of problem. Biochemical oxygen demand (carbonaceous and nitrogenous) is assumed to be removed by an exponential relationship as shown in equations 1 and 2:

$$\frac{dL}{dt} = - K_1 L \qquad (1)$$

$$\frac{dN}{dt} = - K_3 N \qquad (2)$$

where

t = time
L = carbonaceous biochemical oxygen demand concentration
N = nitrogenous biochemical oxygen demand concentration
K_1, K_3 = bio-oxidation rates

The exponential relationship as defined by the above equations assumes that the rate of removal of a compound (the rate of degradation) is proportional to the concentration of that compound remaining in solution. These equations have been found to approximate the rate of decay of the biochemical oxygen demand within most stream systems. The bio-oxidation rates for carbonaceous biochemical oxygen demand (K_1), and for the nitrogenous biochemical oxygen demand (K_3) are considered to be constant for each user-specified stream reach being simulated. The user may specify a different K_1 and K_3 value for each stream reach in the basin. It has been shown in practice that K_1 and K_3 are proportional to the distance from the most recent waste discharge and decrease with increasing distance and time of travel from the point of discharge. The occurrence of several waste discharges along a given stream reach vastly complicates the problem of developing the bio-oxidation rate constants. The ideal method for determining K_1 and K_3 is to measure these values in the field with a complete dissolved oxygen/biochemical oxygen demand field survey. Unfortunately, this type of survey is expensive and

seldom possible, and it thus becomes necessary to estimate values for the bio-oxidation constants. The most appropriate means for estimating these constants is to review the literature to find bio-oxidation rates for wastes with characteristics similar to those wastes entering the stream system to be modeled. The estimations of the bio-oxidation rates, K_1 and K_3 (to the Naperian base), are read into the model for each reach of the stream system being studied. Judicious selection of these rates will permit accurate simulation of the modeled river system.

The computation of atmospheric reaeration is one of the most important parts of the stream dissolved oxygen model. The equation used by the model to compute the reoxygenation rate in the stream is:

$$\frac{dC}{dt} = K_2(C_{SAT} - C)$$

where

C = dissolved oxygen concentration

C_{SAT} = dissolved oxygen saturation concentration

K_2 = reaeration coefficient

t = time

This equation is based on the Fickian law of diffusion and states that the rate of diffusion of dissolved oxygen into the stream is proportional to the difference between the oxygen concentration within the stream and the concentration the stream would have if it were completely saturated with oxygen at the existing temperature and elevation.

Equations 1, 2, and 3 are combined and integrated to obtain the relationship between dissolved oxygen replenishment and decay within a stream system. The solution of this equation in the form used in this model is commonly known as the Streeter-Phelps dissolved oxygen sag equation.

The original Streeter-Phelps equation for dissolved oxygen concentration within a stream does not include nitrogenous biochemical oxygen demand as a major dissolved oxygen sink within the stream system. Recent investigation has revealed that nitrogenous oxygen demand is in fact one of the principal oxygen sinks in many of the stream systems within the United States, and for this reason, the nitrogenous biochemical oxygen demand reaction is included in the DOSAG-I quality routing model. The integrated form of the dissolved oxygen equation as used in this model is shown in equation 4.

$$C(t) = C_{SAT} + \frac{K_1 L_o}{K_2 - K_1} (e^{-K_2 t} - e^{-K_1 t}) + \frac{K_3 N_o}{K_2 - K_3} (e^{-K_2 t} - e^{-K_1 t})$$

$$- (C_{SAT} - C_o) e^{-K_2 t} \qquad (4)$$

where

L_o = initial (ultimate) carbonaceous B.O.D.

N_o = initial (ultimate) nitrogenous B.O.D.

Other sources and sinks of dissolved oxygen may be important in various stream systems, but these are not included in the present model.

An important source of dissolved oxygen is the photosynthetic activity of aquatic plants, both macroscopic and microscopic. This photosynthetic activity increases the dissolved oxygen concentration within the stream during the day, whereas during the hours of darkness the increased respiration of the photosynthetic organisms may cause the dissolved oxygen concentration within the stream to be depressed. These effects may be extremely significant in some streams. Although some work has been done in fitting harmonic functions to various models to account for these photosynthetic effects, to date the coefficients used in these harmonic equations are still a matter of conjecture.

An additional sink of dissolved oxygen is the benthal demand, which is essentially an anaerobic dissolution of settled organic material on the bottom of the stream. This dissolution releases carbonaceous and nitrogenous organic material which in the overlying oxygenated waters exert biochemical oxygen demand. However, the use of a benthal oxygen demand term requires a knowledge of the areal extent of sludge deposits within a stream and the coefficients involved in this dissolution of the settled material.

The coefficients for both photosynthetic activity and benthal oxygen demand are not considered to be well enough known for inclusion in a generalized model of the type of DOSAG-I. As more information on these sources and sinks of oxygen demand become available, the DOSAG-I model will be updated to include the effects of these important factors. In using DOSAG-I, the user should be aware of the fact that not all of the known sinks and sources of oxygen within the stream system are simulated. However, the model, as constructed, should provide the engineer with a good description of the stream system, and from this he can use his judgement of the possible effects of the other important factors on the oxygen resources predicted by the model.

A La Grangian solution technique is used to solve the dissolved oxygen equation in the DOSAG-I quality routing model. This solution

technique involves using a coordinate system which moves with a particle of water in its path down the stream. The La Grangian coordinate system allows a relatively simple computational technique to be used and reduces the computer time required to solve a given problem.

At each change in reach and at every junction a simple mass balance is performed to arrive at the biochemical oxygen demand and dissolved oxygen concentrations in the next reach downstream. In this way, the stream system is modeled from its upper to its lower end recording its response to all of the pollutional loads imposed on it. The reader is referred to the bibliography in this manual if more information is desired regarding the solution technique used or the assumptions made in the derivation of the various equations used in the DOSAG-I model.

MODEL USAGE

In order to use the DOSAG-I Quality Routing Model, the user must take the stream system which he proposes to simulate and break it down into the elements which are used as input to the program. Figure I shows a schematic diagram of a typical river system which has been decomposed into the elements required to model it using DOSAG-I. There are essentially four major elements into which a system must be decomposed so that it can be modeled using this program. These elements are

(1) junctions - the confluence between two streams within the river basin being modeled,

(2) stretches - the length of a river between junctions,

(3) headwater stretches - the length of a river from its headwater to its first junction with another stream, and

(4) reaches - the subunits which comprise a stretch (headwater or normal).

A new reach is designated at any point in the stretch where there is a significant change in the hydraulic, biologic, or physical characteristics of the channel, including the addition of a waste load, or the withdrawal of water from the stream.

After a stream has been represented schematically, it is necessary to specify the hydraulic and physical characteristics of each reach in the stream system. This step involves reading into the program various coefficients to describe all of the factors which are involved in the decay of biochemical oxygen demand, and the replenishment and depletion of dissolved oxygen within the stream system. It should be noted that this is some of the most important information required for the simulation process. The

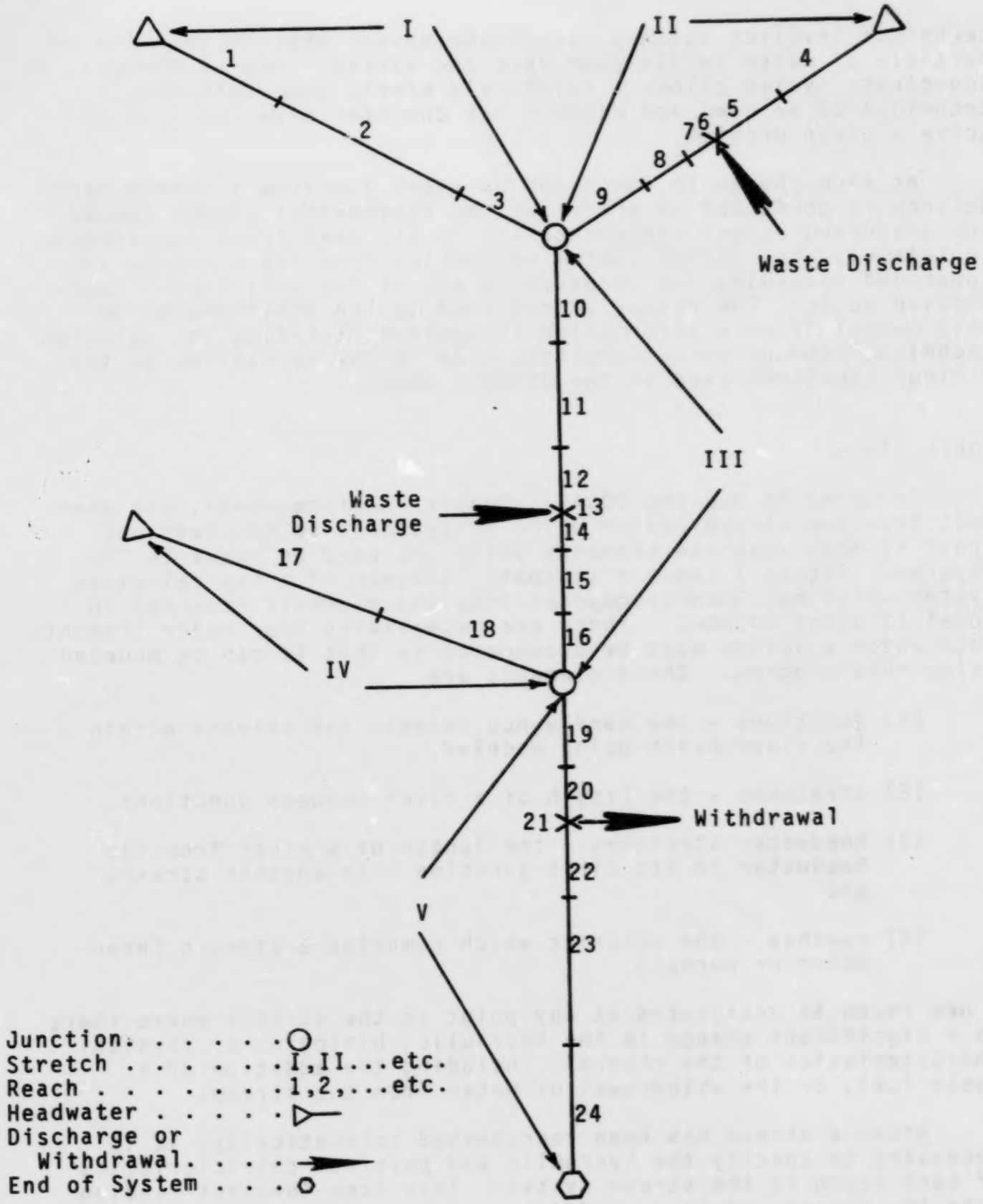


FIGURE I

SCHEMATIC DIAGRAM OF A
TYPICAL RIVER SYSTEM

results obtained from the simulation of the dissolved oxygen resources within a river system, using DOSAG-I as a modeling medium, are only as accurate as the input data provided for the modeling process. It thus behooves the user to take great care in specifying the coefficients to be used in the program for simulating the stream system.

Two equations are used to describe the hydraulic characteristics of each reach in the river system. The first equation represents the relationship between discharge and velocity, and the second between discharge and depth. It is assumed that both of these relationships can be represented by exponential equations as shown below:

$$V = A_1 Q^{B1} \quad (5)$$

$$D = A_2 Q^{B2} \quad (6)$$

where

V = mean velocity in a reach (fps)
Q = mean discharge in a reach (cfs)
D = mean depth (feet)
A_1, A_2, B_1, B_2 = coefficients

The above regression coefficients are used as input data into the program. These coefficients must be developed from data obtained from the actual stream system. The most readily available data of this type are those collected by the U.S. Geological Survey at each of its streamflow gaging station sites. Data from other sources, but of the same type, in a given river basin, can also be very useful to the modeling process. If the type of data necessary to develop these relationships are not available for a given stream, it will be necessary to estimate these coefficients based on the known topography and physical characteristics of the stream. However, this method is subject to serious error and is not recommended unless absolutely necessary.

An extremely important factor in the dissolved oxygen modeling of a stream system is the reaeration coefficient, K_2, which is used in the calculation of the rate of diffusion of dissolved oxygen into the stream. There are four options available in this program for specifying the reaeration rate coefficient. One option is to read it in for each of the reaches in the stream system. The read-in values of K_2 should be to the Naperian logarithmic base. Read-in values might be used if, for example, field surveys of the stream to be modeled have been made and values of the reaeration coefficient have been computed from the results of these. However, the reaeration coefficients determined from surveys of this type are only useful for the discharges measured during the survey period. A change in discharge in the stream would probably result in greatly different values for this coefficient. The program user may also choose to estimate K_2 values for each

reach, based on the known physical and hydraulic characteristics of the stream being modeled. Obviously, this method is very subjective and may involve large errors.

Several investigators have found that the reaeration coefficient, K_2, can be represented by a relationship as shown in equation 7.

$$K_2 = \frac{A_3 V^{B3}}{D^{C3}} \qquad (7)$$

where

A_3, B_3, C_3 = coefficients

This relationship postulates that the reaeration rate coefficient is directly proportional to the mean stream velocity and inversely proportional to the mean depth. It is based on two observed phenomena:

- increasing velocity and turbulence increases the surface renewal rate of dissolved oxygen and promotes mixing and dispersion of the oxygen throughout the depth of the stream, and

- increased depth decreases the rate of dispersion of dissolved oxygen throughout the water mass, thus resulting in lower quantities of oxygen being transferred from the atmosphere.

Several investigators have presented the necessary coefficients for use in equation 7 to calculate the reaeration coefficient for any stream in which the mean velocity and mean depth are known. Table I presents these coefficients as determined by four investigators in both field and laboratory tests. The coefficients developed by Churchill in 1962 and by Langbein and Durum in 1967 are probably the best known for the computation of the reaeration rate coefficient for general model use.

TABLE I

COEFFICIENTS FOR COMPUTATION OF THE REAERATION COEFFICIENT

Investigator	A_3	B_3	C_3
Churchill, et al. (1962)	5.026	0.969	1.673
Langbein and Durum (1967)	3.3	0.50	1.33
O'Connor and Dobbins (1958)	12.90	0.50	1.50
Owens and Gibbs (1969)	9.4	0.67	1.85

If equation 7 is desired to be used for the calculation of the reaeration rate coefficient, the appropriate coefficients in this equation are read into the program for every reach in which it is desired to calculate K_2 in this manner. A note of caution should be observed when using an equation of this form. Mean stream depths of less than one foot cause the reaeration coefficients predicted by the equation to be higher than are normally observed under actual field conditions. If the stream being modeled has significant areas in which the mean depth of flow is less than one foot, the user is advised to employ alternative methods for computing the reaeration coefficient in these areas.

Another technique for computing the reaeration coefficient, also available to the user of this program, is a direct proportionality between the reaeration coefficient and the stream discharge. This relationship is shown in equation 8:

$$K_2 = A_4 Q^{B4} \qquad (8)$$

A relationship of this type may be developed from data obtained from a field survey of a stream in which mean velocity and depth were not determined but discharge was known. The coefficients used in the discharge-reaeration coefficient equation must be computed from measured field data. Equation 8 is not generally applicable to most river systems, because many of the factors which effect the reaeration coefficient are not adequately described by a simple discharge-reaeration coefficient relationship.

The fourth technique available for computing the reaeration coefficient for each reach is based on the investigation by Thackston and Krenkle. This technique was developed experimentally by determining the reaeration coefficient in laboratory channels, using as parameters the mean velocity, channel slope, and mean depth. Equation 9 shows the solution for the reaeration coefficient as developed by Thackston and Krenkle, and as is used in this program:

$$K_2 = 0.00125 \left(1 + \left(\frac{V}{(gD)^{\frac{1}{2}}}\right)^{\frac{1}{2}}\right) (S_e)^{\frac{1}{2}} \left(\frac{g}{D}\right) \qquad (9)$$

where

S_e = mean channel slope (feet/feet)

Use of this option requires that the program user specify a mean channel slope for each reach in the river system being modeled. Equation 9 indicates that the reaeration coefficient is proportional to the shear velocity developed within the stream. Thackston and Krenkle applied this equation to their laboratory data and showed that it gave a reasonably good description of the reaeration rate in the channel. However, only limited data were available

to verify the predictive capability of this equation in an actual stream system. Studies at the Texas Water Development Board have indicated that equation 9 may tend to give higher values for reaeration coefficients than are actually measured during the field evaluation of Texas streams.

The program user may specify any of the four methods described above for the prediction of the reaeration rate coefficient for a given reach. The use of equations 7 and 8 for reaeration coefficient computation require the user to specify the appropriate coefficients for the equations. Equation 9 requires the program user to specify the mean channel slope in feet per foot for each reach for which this equation is to be used. The user may elect to use the same technique for calculating the reaeration coefficient for all reaches in the stream system or he may use a different method for each of the reaches in the system, depending upon the degree of knowledge obtained of the physical and hydraulic characteristics of each reach.

Waste discharges are entered into the system by specifying a new reach at each location at which a discharge takes place. The reach specified should be of zero length and should be located at the nearest river mile to the site of the actual waste discharge in the prototype system. The user specifies the waste discharge volume in cubic feet per second, and the carbonaceous and nitrogenous biochemical oxygen demand concentrations in milligrams per liter. A provision is available in this program to reduce the effluent loadings from a waste discharge by the application of a treatment factor which is read into the program for both the carbonaceous and nitrogenous B.O.D.s in percent. If the treatment factor is to be used, it is assumed that the biochemical oxygen demand concentrations of the waste, as read into the porgram, are actually the concentrations present in the raw wastewater prior to waste treatment. If the user desires to suppress this option, he inserts treatment factors of 0.01 for both the nitrogenous and carbonaceous B.O.D.s for each waste treatment plant. In effect, this means that the B.O.D. values specified for each waste treatment plant will be used in the program as effluent B.O.D. values and will not be changed in any manner by the model.

The model has provisions for withdrawing water at any location within the stream system. The water is withdrawn from the stream at the quality existing at the location of the withdrawal as determined by the model. The withdrawal is specified in the same manner as a waste input to the stream system. A separate reach of zero length is set up for each withdrawal in the system. A negative flow is specified on the waste and withdrawal input cards to indicate that water is being withdrawn from the system. The B.O.D. and treatment factor values for withdrawal are not taken into consideration by the model.

The DOSAG-I quality routing model allows the user to specify up to twelve different water temperatures for modeling the stream system. The biochemical oxygen demand and dissolved oxygen concentrations are computed by the model for each of the temperatures specified. The model modifies the bio-degradation coefficients, K_1 and K_3, and the reaeration coefficient, K_2, for each of the temperatures used in the routing computations. Equations 10 and 11 show the relationships used to modify these rate constants for the remperature changes:

$$K_d(T) = K_d(20°C)\ 1.047^{(T-20)} \qquad (10)$$

$$K_2(T) = K_2(20°C)\ 1.0159^{(T-20)} \qquad (11)$$

where

$K_d = K_1$ or K_3

T = temperature in degrees centigrade

The 20 degree centigrade values for these rate coefficients are the values which have been specified by the user for the particular run being made. The coefficients used to modify the K_1 and K_2 rate terms have been established from field data by a number of investigators and represent the best information available for this modification. The variation in K_3 with temperature is not well established so the K_1 modification is used pending the development of a better relationship.

The user of the DOSAG-I Quality Routing Model has several options available which will enable him to simulate several different stream conditions in one computer run, without reading in additional data. The user of the program may read in up to four carbonaceous and nitrogenous biological waste treatment factors. The program will calculate a new dissolved oxygen profile based on the organic load released from each plant after the treatment factor has been applied. This process is repeated for each of the treatment factors entered in the program. The user may also specify up to four dissolved oxygen target levels, which are the minimum permissable dissolved oxygen concentrations in the stream system. By specifying a dissolved oxygen target level, the user also indicates that he wishes the program to calculate the flow augmentation requirements, if any, needed to meet this target level. The other option available to the user is that up to twelve different temperatures and corresponding headwater flows may be specified, and the program will completely model the stream for each value. The above three options enable the program user, in a single run, to perform a large number of simulations of the stream system to determine the effects of various waste loadings, temperatures, and dissolved oxygen target levels on the dissolved oxygen concentration within the system.

The procedure used by the DOSAG-I Quality Routing Model to determine augmentation requirements should be briefly mentioned. The model begins routing organic wastes and dissolved oxygen from the uppermost point in the stream system and proceeds downstream. As the simulation progresses downstream, reach by reach, the calculated dissolved oxygen concentration is checked against the target dissolved oxygen level specified by the user. When the model discovers a dissolved oxygen concentration below the target, it stops at this reach. The model then searches all of the upstream headwaters to see which headwaters have water available for flow augmentation purposes. The model then estimates, using a parabolic relationship between dissolved oxygen deficit and the target dissolved oxygen level, the quantity of water required for flow augmentation to increase the minimum dissolved oxygen concentration to the target level. The volume of water required is then divided equally among all of the headwaters from which water is available for augmentation. These new flows are then re-routed through the stream system. If the amount of augmentation was insufficient to raise the minimum dissolved oxygen concentration above the target level at the reach being investigated, the process is repeated until the target dissolved oxygen concentration is attained. After the target dissolved oxygen concentration has been satisfied, the program proceeds downstream until it comes to another dissolved oxygen concentration level below the target and then the process is repeated as before. The program is designed so that it can only augment from a headwater stretch, and the augmentation requirements are divided equally among all the headwater stretches which have augmentation availability. The flow augmentation option is suppressed by specifying a negative value for the target dissolved oxygen concentration.

MODEL VERIFICATION AND SENSITIVITY

In order to assess the accuracy and sensitivity of the stream simulation capability of DOSAG-I, it was used to model the upper portion of the San Antonio River Basin. Data are available on the physical, hydraulic, and biological characteristics of this basin, and it has been used previously to verify the TWDB finite-difference water quality simulation model, QUAL-I (see TWDB Report, "Simulation of Water Quality in Streams and Canals").

A schematic diagram of the modeled portion of the San Antonio River Basin is shown in Figure II. Data on the physical and hydraulic characteristics of the San Antonio and Medina Rivers were obtained from data collected by the U.S.G.S at the streamflow gaging stations in the area. Additional information was obtained from the San Antonio River Authority, and from personal observations by the TWDB staff members. This information was used to develop the necessary model input data.

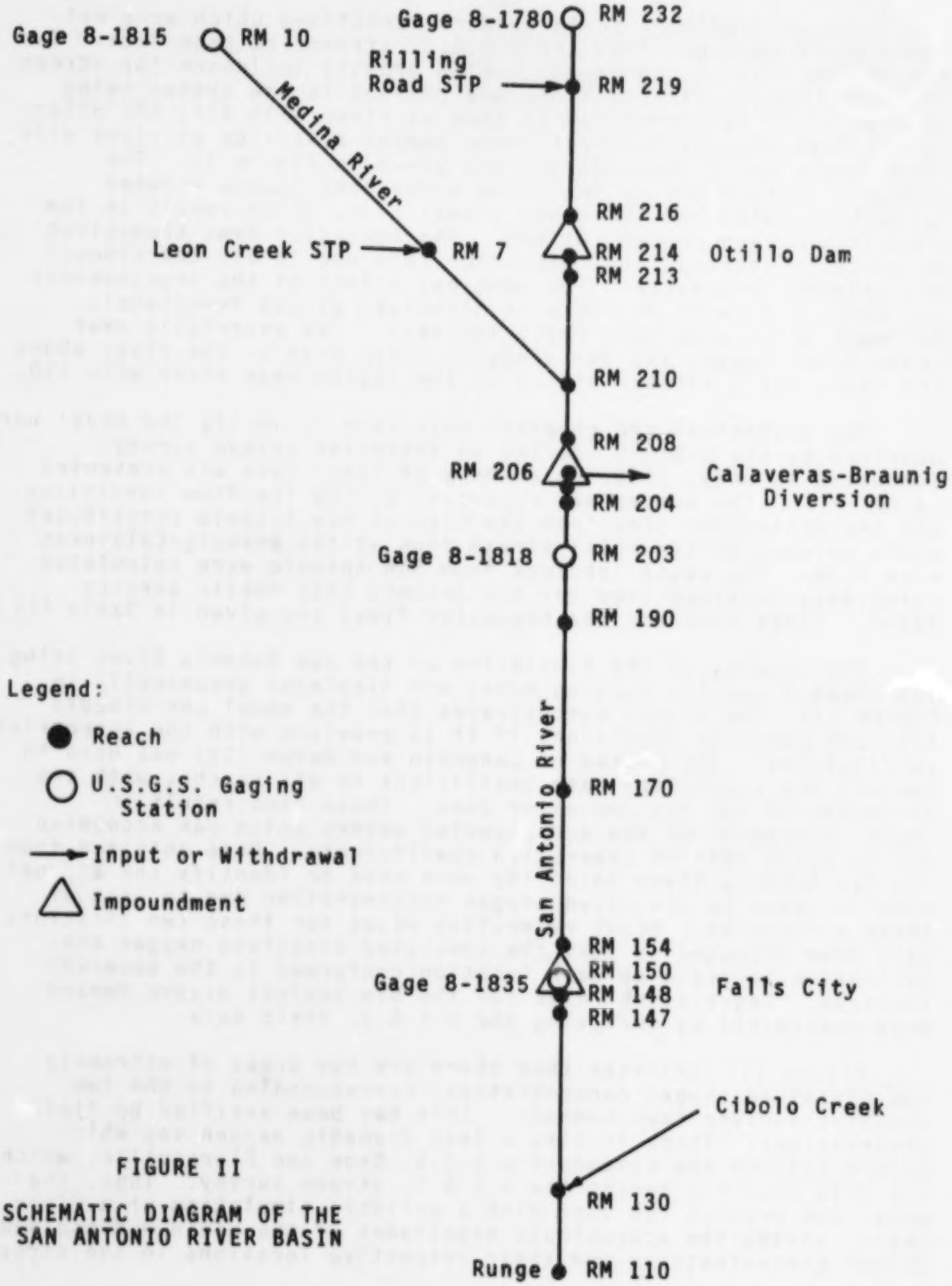


FIGURE II

SCHEMATIC DIAGRAM OF THE SAN ANTONIO RIVER BASIN

Several prominent features were identified which were not immediately apparent from the U.S.G.S. streamflow gage data. Two run-of-the-river impoundments, which greatly influence the stream dissolved oxygen distribution, are present in the system being modeled. One is Otillo Dam located at river mile 214; the other is the Lake Braunig-Lake Calaveras pumped diversion at river mile 205. These small impoundments are shown in Figure II. The backwater effect due to these low water dams causes reduced reaeration rates and increased travel times which result in low dissolved oxygen concentrations. The low-water dams themselves drastically increase the reaeration rate due to air entrainment and extreme turbulence. The combined effect of the impoundments and dams is a rapid decrease in dissolved oxygen immediately followed by an even more rapid increase. The waterfalls near Falls City, Texas, and the sluggish, deep area of the river above the falls has a similar effect on the region near river mile 150.

The biological and chemical data used to verify the model were obtained by the U.S.G.S. during an intensive stream survey conducted in July, 1969. A summary of these data are presented in Table II. The survey was conducted during low-flow conditions and the wastewater flow from the City of San Antonio constituted sixty percent of the total stream flow at the Braunig-Calaveras diversion. The waste loadings from San Antonio were calculated using data obtained from the San Antonio City Public Service Board. These data and the headwater flows are given in Table III.

The results of the simulation of the San Antonio River using the DOSAG-I quality routing model are displayed graphically in Figure III. The figure demonstrates that the model can closely simulate observed conditions if it is provided with the appropriate coefficients. The method of Langbein and Durum (19) was used to compute the reaeration rate coefficient in all reaches with the exception of the two low-water dams. These dams result in rapid reaeration of the deoxygenated waters which was accounted for by using read-in reaeration coefficients. Data obtained from the San Antonio River Authority were used to identify the approximate increase in dissolved oxygen concentration due to each of these structures. Model reaeration rates for these two locations were then adjusted so that the simulated dissolved oxygen concentration increase at each location conformed to the observed increase. Degradation rates for the biochemical oxygen demand were determined by analyzing the U.S.G.S. field data.

Figure III indicates that there are two areas of extremely low dissolved oxygen concentration, corresponding to the two run-of-the-river impoundments. This has been verified by field observations. There is also a less dramatic oxygen sag which occurs between the Elmendorf U.S.G.S. Gage and Floresville, which was also observed during the U.S.G.S. stream survey. Thus, the model can provide its user with a reliable simulation of a river basin, giving the approximate magnitudes of the minimum dissolved oxygen concentrations and their respective locations in the stream.

TABLE II

SUMMARY OF WATER QUALITY DATA FOR THE
SAN ANTONIO RIVER (JUNE, 1969)

Description	Location River Mile	Mean Discharge cfs	Mean B.O.D. mg/l	Mean D.O. mg/l
Farm Road 1518 at Elmendorf	203.0	127.5	14.26	4.97
State Highway 97 near Floresville	175.5	---	6.02	4.81
Falls City Gage	150.5	154.2	3.05	5.68
State Highway 72 near Runge	111.0	---	2.24	7.26

TABLE III

SUMMARY OF INPUTS AND OUTPUTS FOR THE
SAN ANTONIO RIVER (JUNE, 1969)

Description	Location River Mile	Mean Discharge cfs	Mean Ultimate BOD-mg/l	Mean D.O. mg/l
San Antonio River at San Antonio, Gage 8-1780	232	14.0	2.0	7.8
Medina River near San Antonio, Gage 8-1815	10*	60.6	1.0	7.8
Rilling Road Sewage Treatment Plant	219	97.0	52.0	7.0
Leon Creek Sewage Treatment Plant	7*	14.6	42.0	7.5
Braunig-Calaveras Diversion	206	64.0	---	---
Cibolo Creek	130	28.0	1.6	8.0

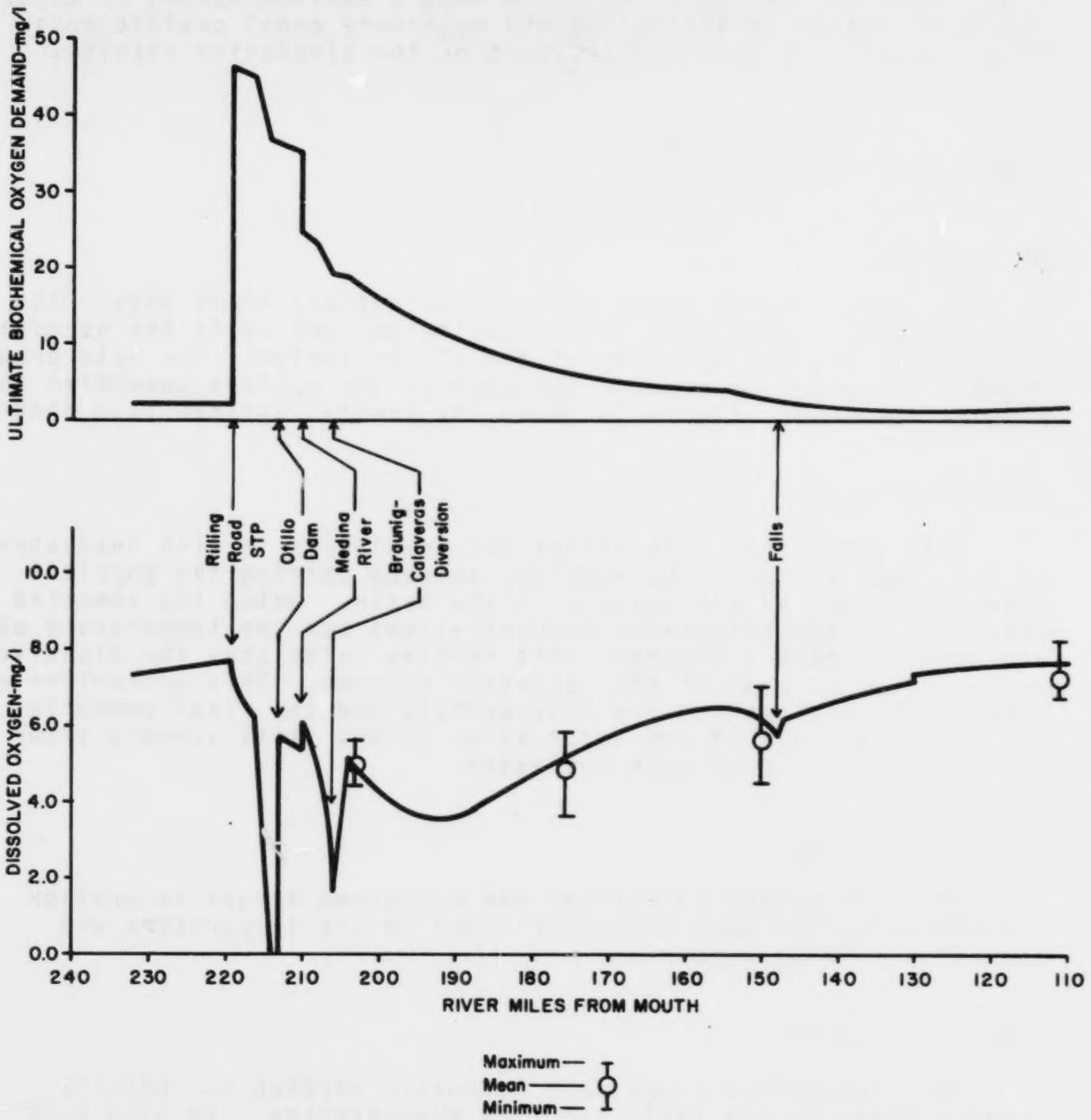


Figure III

DOSAG-I Quality Routing Model San Antonio River

U.S.G.S. Survey Data June 1969

The user is reminded again that the output from the model is only as accurate as the input data, and thus a maximum amount of effort should be placed in evaluating the necessary model coefficients. Only then can the user be confident of the simulation results.

PROGRAM DESCRIPTION

MAIN PROGRAM

The main program reads and echo prints all input data. It sets the basin conditions to be considered, and calls the necessary subroutines for the modeling of the stream system. The main program repeats the modeling process for each of the options specified for program operation. Figure IV shows the general program flow diagram.

SUBROUTINE RUNON

This subroutine initializes the conditions in each headwater of the river system to be modeled, thereby setting the physical characteristics of all reaches in the basin. Using the computed dissolved oxygen saturation concentrations for the temperature and elevation of each headwater, this routine calculates the dissolved oxygen level in each of the headwater reaches. This subroutine also prints the headings for the intermediate and the final summaries, and prints out all of the information in the final summary after all calculations have been completed.

SUBROUTINE DOSAT

This subroutine calculates the dissolved oxygen saturation concentration for each headwater based on the temperature and elevation in that headwater.

SUBROUTINE REINI

This subroutine flags each headwater stretch to indicate whether water is available for flow augmentation. It also sets the initial conditions of a stretch equal to the final conditions of the preceeding stretch. After the calculations for each stretch are completed, including flow augmentation requirements (if any), this subroutine sets the final conditions for each stretch equal to the calculated conditions prior to printout. This procedure is repeated for each of the headwater stretches.

SUBROUTINE TRIBD

Subroutine TRIBD directs the calculation of the dissolved oxygen concentrations for each reach in a stretch, and stores the

minimum concentration in each reach for use in flow augmentation calculations. The calculation of the dissolved oxygen concentration is performed by looping through each reach in the stretch, working downstream until all reaches in the stretch have been considered. The minimum dissolved oxygen concentration in each reach is then stored for later use in the flow augmentation calculations. TRIBD calls Subroutines REPRE and DOEQU to perform the flow augmentation calculations.

SUBROUTINE SCAN

Subroutine SCAN, operating on one stretch at a time, computes the flow augmentation required (if any) to meet the desired target dissolved oxygen concentration at all points in the stretch. It first checks for all available augmentation upstream of the stretch under consideration. The subroutine then determines the minimum dissolved oxygen level in each of the reaches in the stretch. It calculates and stores the dissolved oxygen deficit based on this concentration and the target dissolved oxygen concentration. It then estimates the quantity of dilution water required to satisfy the greatest deficit within the stretch. The required amount of dilution water is divided equally among all sources available for flow augmentation. SCAN then adds the dilution water to each of these upstream sources.

SUBROUTINE REPRE

This subroutine computes all of the constant parameters for the Streeter-Phelps dissolved oxygen sag equation for each reach based on the physical and hydraulic conditions specified by the program user. The reaeration coefficient is the only parameter not computed in this subroutine.

SUBROUTINE DOEQU

DOEQU computes the dissolved oxygen concentration profile and the biochemical oxygen demand profile for each stretch in the stream system being modeled. All of the dissolved oxygen and biochemical oxygen demand computations proceed downstream. Each reach in the stretch is divided into ten sub-reaches and each sub-reach is then considered in order. The discharge entering each sub-reach is calculated based on the discharge in the preceeding sub-reach. The velocity and time of travel is calculated for each sub-reach from the discharge entering the sub-reach. The Streeter-Phelps equation is then employed, with the appropriate parameters, to compute the dissolved oxygen concentration within the sub-reach being considered. This process is repeated for each sub-reach within each reach and for each reach within the stretch being modeled. Dissolved oxygen concentrations within each reach are stored for later use in flow augmentation computations and printing of the final summary.

SUBROUTINE K2CAL

This subroutine calculates the reaeration rate coefficient for each reach in the river system being modeled. The technique used for calculating the reaeration coefficient is specified by the user in the input data.

SUBROUTINE CHKPO

This subroutine calculates the velocity and travel time within a reach using the exponential function, as previously described, with the coefficients provided by the user.

SUBROUTINE CMIN

For each reach, this routine finds the sub-reach having the lowest dissolved oxygen concentration, and the river mile at which this concentration occurs.

SUBROUTINE RMATC

Subroutine RMATC identifies the headwater stretches as they enter a junction. As computations in the program progress downstream, RMATC stores and flags the headwater sources which are available for flow augmentation. This flagging operation is performed each time a junction within the river basin system is encountered.

SUBROUTINE BLEND

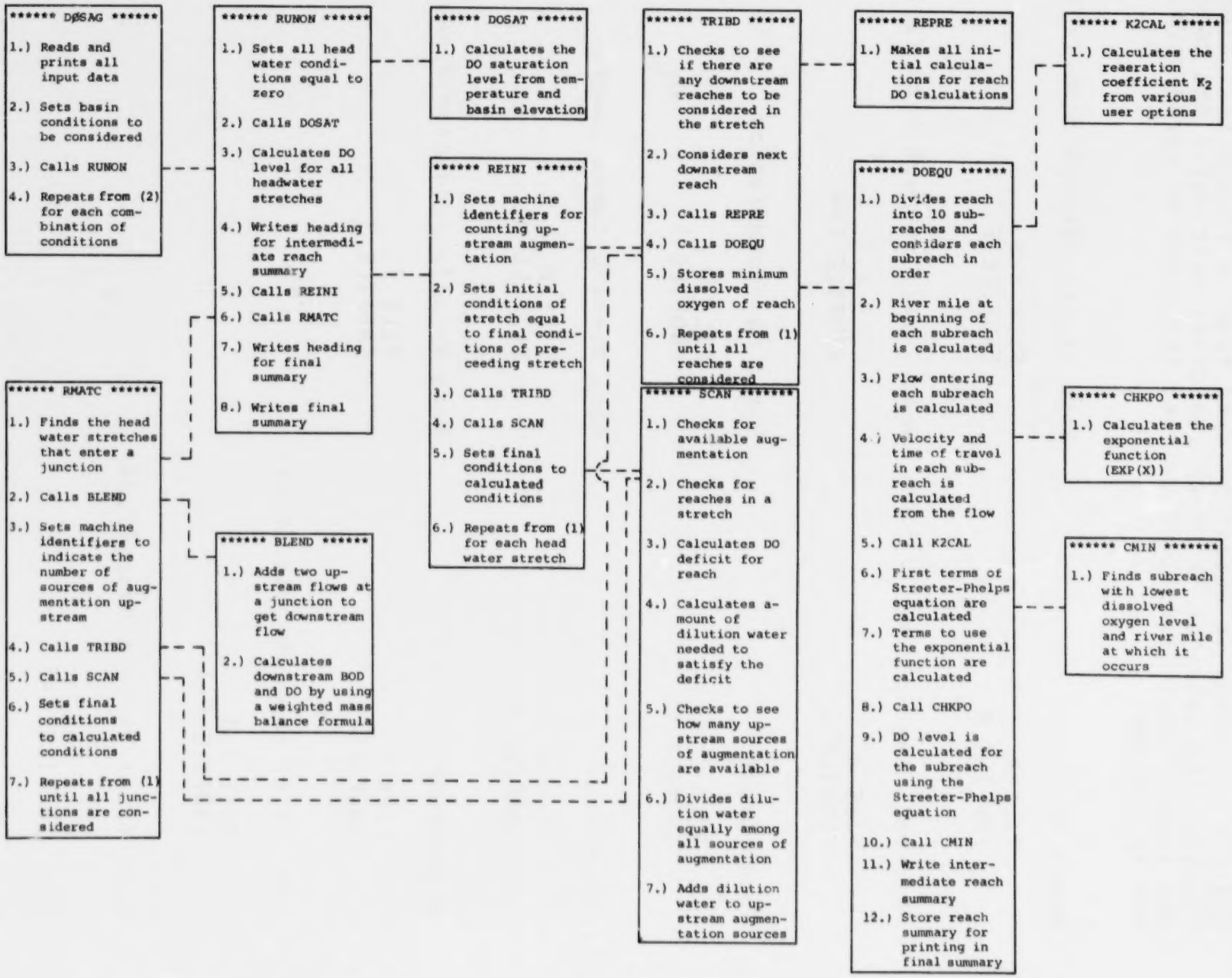
This subroutine computes the discharges and the biochemical oxygen demand and dissolved oxygen concentrations entering a stretch immediately downstream from a junction. Discharges are computed by simple addition; biochemical oxygen demand and dissolved oxygen concentrations are computed by a mass balance at the junction.

PROGRAM DEVELOPMENT

The DOSAG-I program was originally developed for the Federal Water Pollution Control Administration (now Water Quality Office, Environmental Protection Agency) and was made available to the Texas Water Development Board by that agency. Initial program revisions were made by David Peters of the Water Development Board. Additional revisions to the coding and the complete modification of the input and output formats were made by William A. White and Lial F. Tischler of the Systems Engineering Division of the Texas Water Development Board in 1970. Any inquiries concerning the use of the DOSAG-I model should be directed to the latter two individuals.

FIGURE IV

GENERAL PROGRAM FLOW DIAGRAM


****** DOSAG ******
1.) Reads and prints all input data
2.) Sets basin conditions to be considered
3.) Calls RUNON
4.) Repeats from (2) for each combination of conditions
****** RUNON ******
1.) Sets all head water conditions equal to zero
2.) Calls DOSAT
3.) Calculates DO level for all headwater stretches
4.) Writes heading for intermediate reach summary
5.) Calls REINI
6.) Calls RMATC
7.) Writes heading for final summary
8.) Writes final summary
****** DOSAT ******
1.) Calculates the DO saturation level from temperature and basin elevation
****** REINI ******
1.) Sets machine identifiers for counting upstream augmentation
2.) Sets initial conditions of stretch equal to final conditions of preceeding stretch
3.) Calls TRIBD
4.) Calls SCAN
5.) Sets final conditions to calculated conditions
6.) Repeats from (1) for each head water stretch
****** TRIBD ******
1.) Checks to see if there are any downstream reaches to be considered in the stretch
2.) Considers next downstream reach
3.) Calls REPRE
4.) Calls DOEQU
5.) Stores minimum dissolved oxygen of reach
6.) Repeats from (1) until all reaches are considered
****** REPRE ******
1.) Makes all initial calculations for reach DO calculations
****** K2CAL ******
1.) Calculates the reaeration coefficient K_2 from various user options
****** DOEQU ******
1.) Divides reach into 10 subreaches and considers each subreach in order
2.) River mile at beginning of each subreach is calculated
3.) Flow entering each subreach is calculated
4.) Velocity and time of travel in each subreach is calculated from the flow
5.) Call K2CAL
6.) First terms of Streeter-Phelps equation are calculated
7.) Terms to use the exponential function are calculated
8.) Call CHKPO
9.) DO level is calculated for the subreach using the Streeter-Phelps equation
10.) Call CMIN
11.) Write intermediate reach summary
12.) Store reach summary for printing in final summary
****** CHKPO ******
1.) Calculates the exponential function (EXP(X))
****** CMIN ******
1.) Finds subreach with lowest dissolved oxygen level and river mile at which it occurs
****** RMATC ******
1.) Finds the head water stretches that enter a junction
2.) Calls BLEND
3.) Sets machine identifiers to indicate the number of sources of augmentation upstream
4.) Calls TRIBD
5.) Calls SCAN
6.) Sets final conditions to calculated conditions
7.) Repeats from (1) until all junctions are considered
****** BLEND ******
1.) Adds two upstream flows at a junction to get downstream flow
2.) Calculates downstream BOD and DO by using a weighted mass balance formula
****** SCAN ******
1.) Checks for available augmentation
2.) Checks for reaches in a stretch
3.) Calculates DO deficit for reach
4.) Calculates amount of dilution water needed to satisfy the deficit
5.) Checks to see how many upstream sources of augmentation are available
6.) Divides dilution water equally among all sources of augmentation
7.) Adds dilution water to upstream augmentation sources

INPUT FILE DESCRIPTION

All of the input data required by DOSAG-I are in card form. The card data are itemized on the input forms shown in Figure V, and are described in detail by card type in Figure VI. Figure VII displays the sequence in which the cards must enter the computer. The input format is quite flexible; the types of cards permitted are as follows:

Basin Title

FILE A
ENDFILE A

Physical Description

FILE B
ENDFILE B

Reach Order

FILE C
ENDFILE C

Junctions

FILE D
ENDFILE D

Headwaters

FILE E
ENDFILE E

Data (I,1) through Data (I,6)

FILE F-1
ENDFILE F-1

Data (I,7) through Data (I,14)

FILE F-2
ENDFILE F-2

Data (I,15) through Data (I,20)

FILE F-3
ENDFILE F-3

Data (I,21) through Data (I,23)

FILE F-4
ENDFILE F-4

Basin Characteristics

FILE G
ENDFILE G

Mean Monthly Temperatures

FILE H
ENDFILE H

Mean Monthly Headwater Flows

FILE I
ENDFILE I

TEXAS WATER DEVELOPMENT BOARD
STREAM QUALITY ROUTING MODEL
DOSAG-I

Keypunch 026 029

User_____ Form (A) of (E) **FILE A - BASIN TITLE** Page____of____

CARD TYPE (one card only)	Any 72 Alphanumeric Characters May Be Used
FILE A	
ENDFILE A	

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

FILE B - PHYSICAL DESCRIPTION

CARD TYPE (one card only)	NUMBER OF HEADWATER REACHES (Maximum of 10)	NUMBER OF JUNCTIONS (Maximum of 20)	NUMBER OF REACHES (Maximum of 50)	NUMBER OF STRETCHES (Maximum of 20)	INSERT 1 FOR FINAL SUMMARY ONLY		MEAN ELEVATION OF BASIN*
FILE B							
ENDFILE B							

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

FILE C-REACH ORDERING

CARD TYPE (Maximum of 20)	ORDER NO. OF STRETCH	List in Order (Upstream to Downstream) All Reaches In Each Stretch 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
FILE C	1	
FILE C	2	
FILE C	3	
FILE C	4	
FILE C	5	
FILE C	6	
FILE C	7	
FILE C	8	
FILE C	9	
FILE C	0	
ENDFILE C		

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

* *Left justify data and insert decimal point; all other numeric fields are integer and require right justification without decimal point.*

FIGURE V

TEXAS WATER DEVELOPMENT BOARD
STREAM QUALITY ROUTINE MODEL
DOSAG-I

Keypunch 026 029 Page____of____

User_____ Form (B) of (E)

FILE D - JUNCTIONS

CARD TYPE (Maximum of 10)	ORDER NO. OF JUNCTION	List Stretches That Form Each Junction: UPSTREAM STRETCH NO.	UPSTREAM STRETCH NO.	DOWNSTREAM STRETCH NO.
FILE D	01			
FILE D	02			
FILE D	03			
FILE D	04			
FILE D	05			
FILE D	06			
FILE D	07			
FILE D	08			
FILE D	09			
FILE D	10			
ENDFILE D				

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

FILE E - HEADWATER DATA

CARD TYPE (Maximum of 20)	ORDER NO. OF HEADWATER STRETCH	INSERT 1 FOR FLOW AUGMENTATION	INITIAL PERCENT OF D.O. SATURATION*	CARBONACEOUS B.O.D. OF INITIAL FLOW*	NITROGENOUS B.O.D. OF INITIAL FLOW*
FILE E	1				
FILE E	2				
FILE E	3				
FILE E	4				
FILE E	5				
FILE E	6				
FILE E	7				
FILE E	8				
FILE E	9				
FILE E	0				
ENDFILE E					

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

* *Left justify data and insert decimal point; all other numeric fields are integer and require right justification without decimal point.*

FIGURE V

TEXAS WATER DEVELOPMENT BOARD
STREAM QUALITY ROUTING MODEL
DOSAG-I

Keypunch 026 029

User_____ Form (C) of (E) FILE F(1) - DATA(I,1) THRU DATA(I,6) Page____of____

CARD TYPE (Maximum of 50)		ORDER NO. OF REACH *	LENGTH OF REACH (Miles) *	RIVER MILE TO HEAD OF REACH *	CARBONACEOUS REACTION COEFFICIENT	NITROGENOUS REACTION COEFFICIENT *	COEFFICIENT OF Q FOR VELOCITY EQUATION *	EXPONENT OF Q FOR VELOCITY EQUATION *
FILE F-1		1						
FILE F-1		2						
FILE F-1		3						
FILE F-1		4						
FILE F-1		5						
FILE F-1		6						
FILE F-1		7						
FILE F-1		8						
FILE F-1		9						
FILE F-1		0						
ENDFILE F-1								

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

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FILE F(2) - DATA(I,7) THRU DATA(I,14)

CARD TYPE (Maximum of 50)		ORDER NO. OF REACH	INCREMENTAL (RUNOFF) FLOW DATA				SEWAGE AND INDUSTRIAL FLOW DATA			
			FLOW RATE*	DISSOLVED OXYGEN*	CARBONACEOUS B.O.D.*	NITROGENOUS B.O.D.*	FLOW RATE*	DISSOLVED OXYGEN*	CARBONACEOUS B.O.D.*	NITROGENOUS B.O.D.*
FILE F-2		1								
FILE F-2		2								
FILE F-2		3								
FILE F-2		4								
FILE F-2		5								
FILE F-2		6								
FILE F-2		7								
FILE F-2		8								
FILE F-2		9								
FILE F-2		0								
ENDFILE F-2										

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

* *Left justify data and insert decimal point; all other numeric fields are integer and require right justification without decimal point.*

FIGURE V

TEXAS WATER DEVELOPMENT BOARD
STREAM QUALITY ROUTING MODEL
DOSAG-I

Keypunch 026 029

User_____ Form (D) of (E)

Page____of____

FILE F(3) - DATA(I,15) THRU DATA(I,20)

CARD TYPE (Maximum of 50)	ORDER NO. OF REACH	VALUE FOR K_2* (Option #1)	COEFFICIENT OF V FOR K_2 EQUATION* (Option #2)	EXPONENT OF V FOR K_2 EQUATION* (Option #2)	EXPONENT OF DEPTH FOR K EQUATION* (Option #2)	COEFFICIENT OF Q FOR K_2 EQUATION* (Option #3)	EXPONENT OF Q FOR K_2 EQUATION* (Option #3)
FILE F-3	1						
FILE F-3	2						
FILE F-3	3						
FILE F-3	4						
FILE F-3	5						
FILE F-3	6						
FILE F-3	7						
FILE F-3	8						
FILE F-3	9						
FILE F-3	0						
ENDFILE F-3							

FILE F(4) - DATA(I,21) THRU DATA(I,23)

CARD TYPE (Maximum of 50)	ORDER NO. OF REACH	OPTION FOR CALCULATING K_2	REACH IDENTIFICATION (20 Alphanumeric Characters)	COEFFICIENT OF Q FOR DEPTH EQUATION*	EXPONENT OF Q FOR DEPTH EQUATION*	SLOPE OF CHANNEL FOR K_2 EQUATION* (Option #4)
FILE F-4	1					
FILE F-4	2					
FILE F-4	3					
FILE F-4	4					
FILE F-4	5					
FILE F-4	6					
FILE F-4	7					
FILE F-4	8					
FILE F-4	9					
FILE F-4	0					
ENDFILE F-4						

* Left justify data and insert decimal point; all other numeric fields are integer and require right justification without decimal point.

FIGURE V

TEXAS WATER DEVELOPMENT BOARD
STREAM QUALITY ROUTING MODEL
DOSAG-I

Keypunch 026 029

User_____ Form (E) of (E)

Page____of____

FILE G - BASIN CHARACTERISTICS

CARD TYPE (one card only)		MINIMUM D.O. TARGET LEVELS FOR BASIN				PERCENT TREATMENT FOR BASIN - SEWAGE AND INDUSTRIAL WASTES							
		(1)*	(2)*	(3)*	(4)*	(1) CAR*	(1) NIT*	(2) CAR*	(2) NIT*	(3) CAR*	(3) NIT*	(4) CAR*	(4) NIT*
FILE G													
ENDFILE G													

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

FILE H - MEAN MONTHLY TEMPERATURE

CARD TYPE (one card only)		STREAM TEMPERATURE IN DEGREES CENTIGRADE											
		OCT*	NOV*	DEC*	JAN*	FEB*	MAR*	APR*	MAY*	JUN*	JUL*	AUG*	SEP*
FILE H													
ENDFILE H													

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

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FILE I - MEAN MONTHLY HEADWATER FLOWS

CARD TYPE (Maximum of 10)	ORDER NO. OF HEADWATER STRETCH	HEADWATER FLOWS IN CFS											
		OCT*	NOV*	DEC*	JAN*	FEB*	MAR*	APR*	MAY*	JUN*	JUL*	AUG*	SEP*
FILE I	01												
FILE I	02												
FILE I	03												
FILE I	04												
FILE I	05												
FILE I	06												
FILE I	07												
FILE I	08												
FILE I	09												
FILE I	10												
ENDFILE I													

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

* *Left justify data and insert decimal point; all other numeric fields are integer and require right justification without decimal point.*

FIGURE V

FIGURE VI - DOSAG-1 INPUT FILE DESCRIPTION

CARD OR FIELD ID	DESCRIPTION	PROGRAM VARIABLE
	FILE A - BASIN TITLE	
	Listed below are detailed descriptions of the data required for the name of the basin (two (2) cards).	
FILE A	This data consists of one (1) card. Any alpha-numeric or other permissible character can be supplied to this title data array. Columns (9-80).	TITLE(I)
ENDFILE A	This card must follow the above FILE A card. The computer recognizes this as the last FILE A card and expects FILE B data to follow.	
	FILE B - PHYSICAL DESCRIPTION	
	Listed below are detailed descriptions of the data associated with the physical configuration of the stream system (two (2) cards).	
FILE B	See description below	
	Number of headwater stretches in basin (maximum of 10). Columns (16-20)	NINIT
	Number of junctions in basin (maximum of 20). Columns (26-30).	NJUNC
	Number of reaches in the basin (maximum of 50). Columns (36-40)	NREA
	Number of stretches in the basin (maximum of 20). Columns (46-50).	NTRIB
	Printing option for output; must be 1 or 0. If 1, intermediate summary is suppressed. Columns (56-60).	ICK
	INSERT	
	Mean elevation of the basin in feet. Columns (75-80).	ELEV
ENDFILE B	This card must follow the FILE B card. The computer recognizes this as the last FILE B card and expects FILE C data to follow.	
	*** FILE C - REACH ORDERING***	
	Listed below are detailed descriptions of the data required for ordering the reaches. The reaches are listed in order (upstream to downstream) for each of the stretches, which are also ordered (upstream to downstream). There must be a total of (NTRIB + 1) FILE C cards (one card per stretch and endfile - maximum of 21)	
FILE C	See description below.	
	Order of stretch. Columns (11-15).	I
	Order of each reach (J) in stretch (I). Columns (22-80).	IØRD(I,J)
ENDFILE C	This card must be the last card in FILE C. The computer recognizes this as the last FILE C card and expects FILE D data to follow.	

CARD OR FIELD ID	DESCRIPTION	PROGRAM VARIABLE
	FILE D - JUNCTIONS	
	Listed below are detailed descriptions of the data required for ordering the junctions (upstream to downstream) and the stretches that enter each junction. There must be (NJUNC + 1) FILE D cards (one for each junction and endfile - maximum of 21).	
FILE D	See descriptions below.	
	Order of junction. Columns (21-25).	I
	List of upstream stretches (J=1,2) and downstream stretches (J=3) at a junction (I). Columns (31-35, 41-45, and 51-55).	JUNC(I,J)
ENDFILE D	This card must be the last card in FILE D. The computer recognizes this as the last FILE D card and expects FILE E cards to follow.	
	FILE E - HEADWATER DATA	
	Listed below are the data required for establishing availability of flow augmentation and headwater quality conditions. There must be (NINIT + 1) FILE E data cards (one card per headwater stretch and endfile - maximum of 11).	
FILE E	See description below.	
	Order of headwater stretches. Columns (26-30).	I
	Identification of stretches that have augmentation available. IAUG(I) = 1 if augmentation is available and IAUG(I) = 0 if augmentation is not available. Columns (36-40)	IAUG(I)
	Percent of D.O. saturation in the initial flow in headwater stretch (I). Columns (53-60).	CØNDZ(I,1)
	Carbonaceous B.O.D. of the initial flow in headwater stretch (I) in mg/l. Columns (63-70).	CØNDZ(I,2)
	Nitrogenous B.O.D. of the initial flow in headwater stretch (I) in mg/l. Columns (73-80).	CØNDZ(I,3)
ENDFILE E	This card must be the last card in FILE E. The computer recognizes this as the last FILE E card and expects FILE F(1) cards to follow.	
	FILE F(1) - DATA(I,1) THROUGH DATA(I,6)	
	Listed below are detailed descriptions of DATA(I,1) through DATA(I,6). There must be a total of (NREA + 1) FILE F(1) cards (one card per reach and endfile - maximum of 51).	
FILE F-1	See description below.	
	Order of reach. Columns (16-20)	I
	Length of reach (I) in miles. Columns (23-30).	DATA(I,1)
	River mile to head of reach (I). Columns (33-40).	DATA(I,2)
	Value for carbonaceous reaction coefficient, K_1, for reach (I) in 1/day - base e. Columns (43-50).	DATA(I,3)
	Value for nitrogenous reaction coefficient, K_3, for reach (I) in 1/day - base e. Columns (53-60).	DATA(I,3)

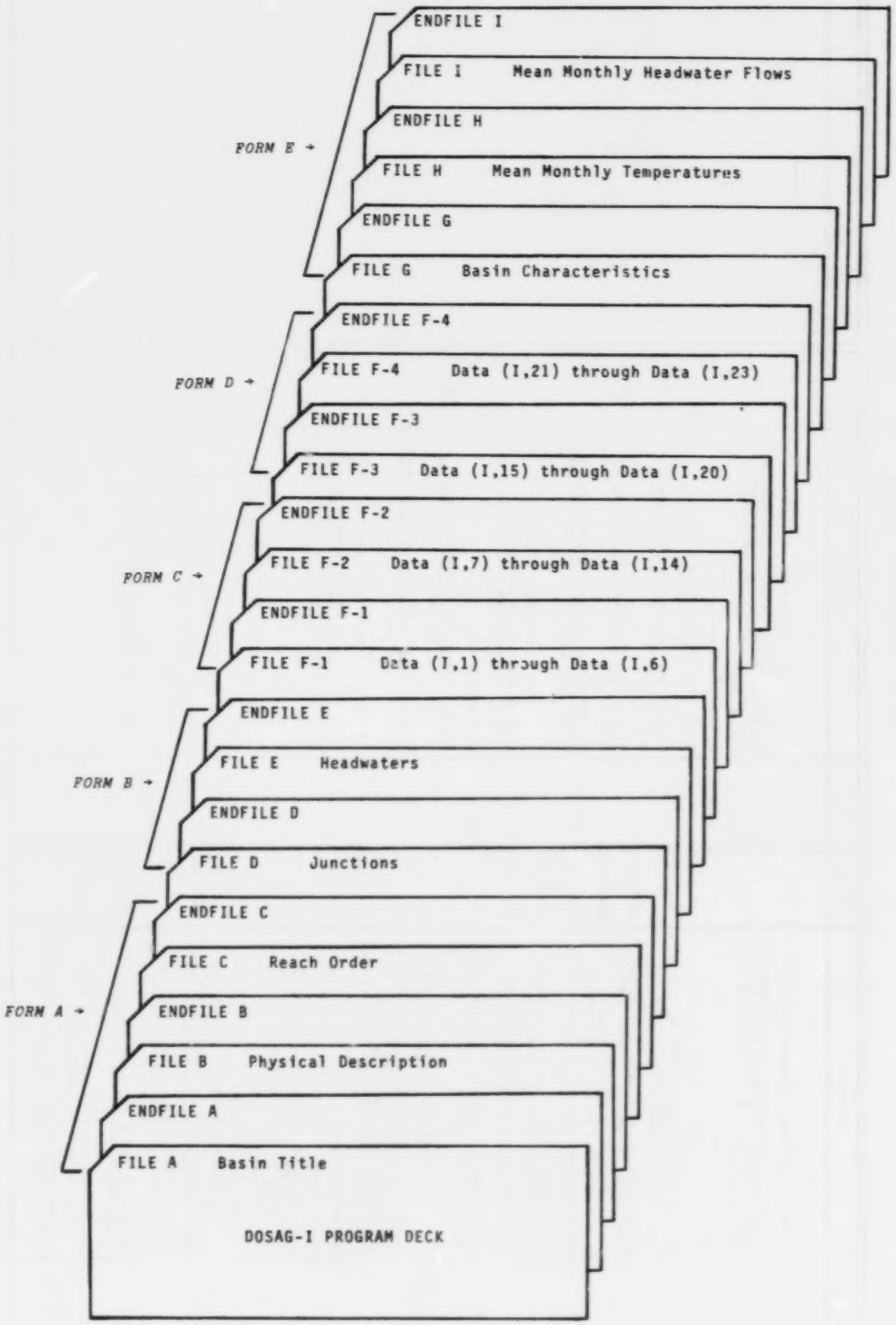
CARD OR FIELD ID	DESCRIPTION	PROGRAM VARIABLE
	Coefficient of discharge used to calculate velocity for reach (I). Columns (63-80).	DATA(I,3)
	Exponent of discharge used to calculate velocity for reach (I). Columns (73-80).	DATA(I,4)
ENDFILE F-1	This card must be the last card in FILE F(1). The computer recognizes this as the last FILE F(1) card and expects FILE F(2) cards to follow.	
	*** FILE F(2) - DATA(I,7) THROUGH DATA(I,14)***	
	Listed below are detailed descriptions of DATA(I,7) through DATA(I,14). There must be a total of (NREA + 1) FILE F(2) cards (one per reach and endfile - maximum of 51).	
FILE F-2	See description below.	
	Order of reach. Columns (16-20).	I
	Discharge of the increment runoff for reach (I) in cfs. Columns (23-29).	DATA(I,7)
	Dissolved oxygen concentration of the incremental runoff for reach (I) in mg/l. Columns (32-36).	DATA(I,8)
	Carbonaceous B.O.D. of the incremental runoff for reach (I) in mg/l. Columns (39-43)	DATA(I,9)
	Nitrogenous B.O.D. of the incremental runoff for reach (I) in mg/l. Columns (46-50).	DATA(I,10)
	Discharge of sewage and industrial waste for reach (I) in mg/l. Columns (53-59).	DATA(I,11)
	Dissolved oxygen concentration of the sewage and industrial discharge for reach (I) in mg/l. Columns (62-66).	DATA(I,12)
	Carbonaceous B.O.D. of the sewage and industrial discharge for reach (I) in mg/l. Columns (69-73).	DATA(I,13)
	Nitrogenous B.O.D. of the sewage and industrial discharge for reach (I) in mg/l. Columns (76-80).	DATA(I,14)
ENDFILE F-2	This card must be the last card in FILE F(2). The computer recognizes this as the last FILE F(2) card and expects FILE F(3) cards to follow.	

FIGURE VI - DOSAG-I INPUT FILE DESCRIPTION

CARD OR FIELD ID	DESCRIPTION	PROGRAM VARIABLE
	FILE F(3) - DATA(I,15) THORUGH DATA(I,20)	
	Listed below are detailed descriptions of DATA(I,15) through DATA(I,20). There must be a total of (NREA + 1) FILE F(3) cards (one per reach and end-file - maximum of 51).	
FILE F-3	See description below.	
	Order of reach. Columns (16-20).	I
	Value for the reaeration coefficient, K_2, if option #1 for calculating K_2 for reach (I) is used in 1/day - base e. Columns (23-30).	DATA(I,15)
	Coefficient of velocity if option #2 is used for calculating K_2 for reach (I). Columns (33-40).	DATA(I,16)
	Exponent of velocity if option #2 is used for calculating K_2 for reach (I). Columns (43-50).	DATA(I,17)
	Exponent of depth if option #2 is used for calculating K_2 for reach (I). Columns (53-60).	DATA(I,18)
	Coefficient of discharge if option #3 is used for calculating k_2 for reach (I). Columns (63-70).	DATA(I,19)
	Exponent of discharge if option #3 is used for calculating K_2 for reach (I). Columns (73-80).	DATA(I,20)
ENDFILE F-3	This card must be the last card in FILE F(3). The computer recognizes this as the last FILE F(3) card and expects FILE F(4) cards to follow.	
	K_2 OPTION, REACH IDENTIFICATION, AND DATA(I,21) THROUGH DATA(I,23)	
	Listed below are detailed descriptions of the K_2 option, reach identification, and DATA(I,21) through DATA(I,23). There must be a total of (NREA + 1) FILE F(4) cards (one per reach and end-file - maximum of 51).	
FILE F-4	See description below.	
	Order of reach. Columns (16-20).	I
	Option for calculating K_2. Insert option number (1-4). Columns (25-26). Option #1: Read in K_2 value Option #2: $K_2 = aV^b/D^c$ Option #2: $K_2 = aV^b/D^c$ Option #3: $K_2 = aQ^b$ Option #4: $K_2 = 10.8[1 + (V/gD)^{0.5}]\frac{g}{D}S_e$	KØPT(I)
	Identification of reach (I). As many as 20 alpha-numeric characters may be used. Columns (31-50).	RIDENT(I,J)
	Coefficient of discharge used in calculating the average depth of water for reach (I). Columns (53-60).	DATA(I,21)
	Exponent of discharge used in calculating the average depth of water for reach (I). Columns (63-70).	DATA(I,22)
	Slope of the channel if option #4 is used to calculate K_2 for reach (I). Columns (73-80).	DATA(I,23)
ENDFILE F-4	This card must be the last card in FILE F(4). The computer recognizes this as the last FILE F(4) card and expects FILE G cards to follow.	

CARD OR FIELD ID	DESCRIPTION	PROGRAM VARIABLE
	FILE G - BASIN CHARACTERISTICS	
	Listed below are detailed descriptions of the data required for specifying target level dissolved oxygen concentrations and degrees of treatment (two (2) cards).	
FILE G	See description below	
	Minimum dissolved oxygen levels in mg/l to be allowed in basin (maximum of 4). Columns (16-35).	DØL(I)
	Treatment factor in percent used for carbonaceous B.O.D. (maximum of 4). Columns (41-45; 51-55; 61-65; 71-75)	TRFAC(I)
	Treatment factor in percent used for nitrogenous B.O.D. (maximum of 4). Columns (46-50; 56-60; 66-70; 76-80).	TRFACN(I)
ENDFILE G	This card must follow the FILE G card. The computer recognizes this as the last FILE G card and expects FILE H data to follow.	
	FILE H - MEAN MONTHLY TEMPERATURES	
	Listed below are detailed descriptions of the data required for specifying the mean monthly temperatures in the basin (two (2) cards).	
FILE H	See description below	
	Mean monthly temperature of water in the basin in degrees Centigrade for season (I) (maximum of 12). Columns (21-80).	TEMMØ(I)
ENDFILE H	This card must follow the FILE H card. The computer recognizes this as the last card in FILE H and expects FILE I cards to follow.	
	FILE I - MEAN MONTHLY HEADWATER FLOWS	
	Listed below are detailed descriptions of the data required for specifying the mean monthly headwater discharges in the basin. There must be a total of (NINIT + 1) FILE I cards (one per headwater and endfile - maximum of 11).	
FILE I	See description below.	
	Order of headwater stretch. Columns (11-15).	I
	Mean monthly headwater discharge in cfs for headwater stretch (I) in season (J) (maximum of 12). Columns (21-80).	HWFLØW(I,J)
ENDFILE I	This card must be the last card in FILE I. The computer recognizes this as the last card in FILE I, and proceeds with execution.	

FIGURE VII
INPUT DATA ORGANIZATION



OUTPUT FILE DESCRIPTION

The output generated by the DOSAG-I model is printer-output and consists of the following three parts:

1) an echo of all input data,

2) an intermediate report, and

3) a final summary.

Example listings of the printer-output for DOSAG-I are shown on the following pages.

-EXAMPLE OUTPUT-

* * * FILE A - BASIN TITLE * * *

CARD TYPE	NAME OF RIVER BASIN
FILE A	SAN ANTONIO RIVER ANALYSIS - DOSAG VERSION
ENDFILE	

* * * FILE B - PHYSICAL DESCRIPTION * * *

CARD TYPE	NO. OF HEADWATERS MAX OF 10	NO. OF JUNCTIONS MAX OF 10	NO. OF REACHES MAX OF 50	NO. OF STRETCHES MAX OF 20	INSERT 1 FOR FINAL SUMMARY	MEAN ELEV. (FT)
FILE B	2	1	21	3	0	510.0
ENDFILE						

* * * FILE C - REACH ORDER * * *

CARD TYPE	NO. OF STRETCH	ORDER OF ALL REACHES IN EACH STRETCH (UPSTREAM TO DOWNSTREAM)																		
FILE C	1	1	2	3	4	5	6	0	0	0	0	0	0	0	0	0	0	0	0	0
FILE C	2	7	8	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FILE C	3	10	11	12	13	14	15	16	17	18	19	20	21	0	0	0	0	0	0	0
ENDFILE																				

* * * FILE D - JUNCTIONS * * *

CARD TYPE	NO. OF JUNCTION	NO. OF UPSTREAM STRETCH	NO. OF UPSTREAM STRETCH	NO. OF DOWNSTREAM STRETCH
FILE D	1	1	2	3
ENDFILE				

* * * FILE E - HEADWATERS * * *

CARD TYPE	NO. OF HEADWATER STRETCH	INSERT 1 FOR AUGMENTATION	PERCENT D.O. SAT.	CARBON. BOD (MG/L)	NITROG. BOD (MG/L)
FILE E	1	1	94.0	2.0	.0
FILE E	2	1	94.0	1.0	.0
ENDFILE					

* * * FILE F(1) - DATA(I,1) THRU DATA(I,6) * * *

CARD TYPE	NO. OF REACH	LENGTH OF REACH (MILES)	RIVER MILE TO HEAD OF REACH	CARBON. REACTION COEF.	NITROG. REACTION COEF.	COEF. ON Q FOR VELOCITY	EXP. ON Q FOR VELOCITY
FILE F-1	1	13.0	232.0	.320	.000	.333	.335
FILE F-1	2	.0	219.0	.320	.000	.118	.673
FILE F-1	3	3.0	219.0	.320	.000	.118	.673
FILE F-1	4	2.0	216.0	.320	.000	.188	.083
FILE F-1	5	1.0	214.0	.320	.000	.118	.673
FILE F-1	6	3.0	213.0	.320	.000	.118	.673
FILE F-1	7	3.0	10.0	.320	.000	.256	.381
FILE F-1	8	.0	7.0	.320	.000	.256	.381
FILE F-1	9	7.0	.0	.320	.000	.256	.381
FILE F-1	10	2.0	210.0	.320	.000	.105	.414
FILE F-1	11	2.0	208.0	.320	.000	.188	.083
FILE F-1	12	.0	206.0	.320	.000	.105	.414
FILE F-1	13	2.0	206.0	.320	.000	.210	.673
FILE F-1	14	14.0	204.0	.320	.000	.105	.414
FILE F-1	15	20.0	190.0	.250	.000	.105	.414
FILE F-1	16	16.0	170.0	.250	.000	.105	.414
FILE F-1	17	6.0	154.0	.250	.000	.188	.083
FILE F-1	18	1.0	148.0	.250	.000	.210	.673
FILE F-1	19	17.0	147.0	.200	.000	.142	.414
FILE F-1	20	.0	130.0	.200	.000	.142	.414
FILE F-1	21	20.0	130.0	.050	.000	.142	.414
ENDFILE							

* * * FILE F(2) - DATA(I,7) THRU DATA(I,14) * * *

CARD TYPE	NO. OF REACH	INCREMENTAL (RUNOFF) FLOWS FLOW RATE	DISS. OXYGEN	CARBON. BOD	NITROG. BOD	SEWAGE AND INDUSTRIAL FLOWS FLOW RATE	DISS. OXYGEN	CARBON. BOD	NITROG. BOD
FILE F-2	1	.0	.0	.0	.0	.0	.0	.0	.0
FILE F-2	2	.0	.0	.0	.0	97.0	7.0	52.6	.0
FILE F-2	3	.0	.0	.0	.0	.0	.0	.0	.0
FILE F-2	4	.0	.0	.0	.0	.0	.0	.0	.0
FILE F-2	5	.0	.0	.0	.0	.0	.0	.0	.0
FILE F-2	6	.0	.0	.0	.0	.0	.0	.0	.0
FILE F-2	7	.0	.0	.0	.0	.0	.0	.0	.0
FILE F-2	8	.0	.0	.0	.0	17.4	7.5	42.6	.0
FILE F-2	9	.0	.0	.0	.0	.0	.0	.0	.0
FILE F-2	10	.0	.0	.0	.0	.0	.0	.0	.0
FILE F-2	11	.0	.0	.0	.0	.0	.0	.0	.0
FILE F-2	12	.0	.0	.0	.0	-64.0	.0	.0	.0
FILE F-2	13	.0	.0	.0	.0	.0	.0	.0	.0
FILE F-2	14	.0	.0	.0	.0	.0	.0	.0	.0
FILE F-2	15	15.0	8.0	4.0	.0	.0	.0	.0	.0
FILE F-2	16	15.0	8.0	4.0	.0	.0	.0	.0	.0
FILE F-2	17	15.0	8.0	4.0	.0	.0	.0	.0	.0
FILE F-2	18	24.0	8.0	2.0	.0	.0	.0	.0	.0
FILE F-2	19	24.0	8.0	2.0	.0	.0	.0	.0	.0
FILE F-2	20	.0	.0	.0	.0	28.0	8.0	1.6	.0
FILE F-2	21	24.0	8.0	2.0	.0	.0	.0	.0	.0
ENDFILE									

* * * FILE F(3) - DATA(1,15) THRU DATA (1,20) * * *

CARD TYPE	NO. OF REACH	VALUE FOR K2 OPTION-1	COEF. ON V FOR K2 OPTION-2	EXP. ON V FOR K2 OPTION-2	EXP. ON D FOR K2 OPTION-2	COEF. ON Q FOR K2 OPTION-3	EXP. ON Q FOR K2 OPTION-3
FILE F-3	1	.000	3.300	1.000	1.330	.000	.000
FILE F-3	2	.000	3.300	1.000	1.330	.000	.000
FILE F-3	3	.000	3.300	1.000	1.330	.000	.000
FILE F-3	4	.000	3.300	1.000	1.330	.000	.000
FILE F-3	5	55.000	.000	.000	.000	.000	.000
FILE F-3	6	.000	3.300	1.000	1.330	.000	.000
FILE F-3	7	.000	3.300	1.000	1.330	.000	.000
FILE F-3	8	.000	3.300	1.000	1.330	.000	.000
FILE F-3	9	.000	3.300	1.000	1.330	.000	.000
FILE F-3	10	.000	3.300	1.000	1.330	.000	.000
FILE F-3	11	.000	3.300	1.000	1.330	.000	.000
FILE F-3	12	.000	3.300	1.000	1.330	.000	.000
FILE F-3	13	35.000	3.300	1.000	1.330	.000	.000
FILE F-3	14	.000	3.300	1.000	1.330	.000	.000
FILE F-3	15	.000	3.300	1.000	1.330	.000	.000
FILE F-3	16	.000	3.300	1.000	1.330	.000	.000
FILE F-3	17	.000	3.300	1.000	1.330	.000	.000
FILE F-3	18	.000	3.300	1.000	1.330	.000	.000
FILE F-3	19	.000	3.300	1.000	1.330	.000	.000
FILE F-3	20	.000	3.300	1.000	1.330	.000	.000
FILE F-3	21	.000	3.300	1.000	1.330	.000	.000

ENDFILE

* * * FILE F(4) - DATA(1,21) THRU DATA(1,23) * * *

CARD TYPE	NO. OF REACH	OPTION FOR K2	NAME OF REACH	COEF. ON Q FOR DEPTH	EXP. ON Q FOR DEPTH	CHANNEL SLOPE OPTION-4
FILE F-4	1	2	SAR HEADWATERS TO RR	.511	.264	.000
FILE F-4	2	2	RILLING ROAD STP	.438	.414	.000
FILE F-4	3	2	RR STP TO SALADO CRK	.438	.414	.000
FILE F-4	4	2	SALADO CRK TO CK DAM	4.100	.116	.000
FILE F-4	5	1	1-MILE BELOW CK DAM	.438	.414	.000
FILE F-4	6	2	BELOW DAM TO MEDINA	.438	.414	.000
FILE F-4	7	2	MEDINA HDWATER TO LC	.299	.361	.000
FILE F-4	8	2	LEON CREEK STP	.299	.361	.000
FILE F-4	9	2	LEON CRK STP TO SAR	.299	.361	.000
FILE F-4	10	2	MR+SAR FOR 3-MI.	.440	.414	.000
FILE F-4	11	2	ABOVE CALV WTHDRL	3.000	.116	.000
FILE F-4	12	2	CALAVERAS WITHDRAWL	.440	.414	.000
FILE F-4	13	1	CALV WDRL FOR 2-MI.	.438	.414	.000
FILE F-4	14	2	CALAVERAS TO EDORF	.440	.414	.000
FILE F-4	15	2	ELMENDORF TO FLORESF	.440	.414	.000
FILE F-4	16	2	FLORES TO FALLS CITY	.440	.414	.000
FILE F-4	17	2	IMPOUNDMENT NR F.C.	3.000	.116	.000
FILE F-4	18	2	FALLS NR F.C.	.438	.414	.000
FILE F-4	19	2	FALLS CITY TO CIBOLO	.440	.414	.000
FILE F-4	20	2	CIBOLO CREEK	.440	.414	.000
FILE F-4	21	2	CIBOLO CRK TO RUNGE	.440	.414	.000

ENDFILE

* * * FILE G - BASIN CHARACTERISTICS * * *

CARD TYPE	MINIMUM ALLOWABLE D.O. LEVEL (MG/L)				PERCENT TREATMENT (M + I FLOWS) CAR	NIT	CAR	NIT	CAR	NIT	CAR	NIT
FILE G	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

ENDFILE

* * * FILE H - MEAN MONTHLY TEMPERATURES * * *

CARD TYPE	STREAM TEMPERATURE IN DEGREES CENTIGRADE OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
FILE H	.0	.0	.0	.0	.0	.0	.0	.0	27.5	.0	.0	.0

ENDFILE

* * * FILE I - MEAN MONTHLY HEADWATER FLOWS * * *

CARD TYPE	NO. OF HEADWATER	HEADWATER FLOWS IN CFS OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
FILE I	1	.0	.0	.0	.0	.0	.0	.0	.0	14.0	.0	.0	.0
FILE I	2	.0	.0	.0	.0	.0	.0	.0	.0	60.6	.0	.0	.0

ENDFILE

*****INTERMEDIATE SUMMARY*****

SAN ANTONIO RIVER ANALYSIS - DOSAG VERSION

NUMBER OF RUN = 1
TREATMENT (C) = .00
SEASON OF YR. = JUN

TARGET D.O. LEVEL = .01
TREATMENT (N) = .00
MEAN TEMPERATURE =27.50

NO. OF REACH	RIVER MILE TO HEAD OF REACH	FLOW RATE (CFS)	D.O. MIN. (MG/L)	RIVER MILE AT MIN. D.O.	DISSOLVED OXYGEN AT START (MG/L)	DISSOLVED OXYGEN AT END (MG/L)	CARBONACEOUS BOD AT START (MG/L)	CARBONACEOUS BOD AT END (MG/L)	NITROGENOUS BOD AT START (MG/L)	NITROGENOUS BOD AT END (MG/L)
1	232.0	14.0	7.49	230.7	7.49	7.71	2.00	1.28	.00	.00
2	219.0	111.0	7.09	219.0	7.09	7.09	46.12	46.12	.00	.00
3	219.0	111.0	6.17	216.0	6.98	6.17	46.12	44.76	.00	.00
4	216.0	111.0	.00	214.0	5.31	.00	44.76	36.71	.00	.00
5	214.0	111.0	.95	213.9	.95	.95	36.71	36.36	.00	.00
6	213.0	111.0	5.35	210.0	5.55	5.35	36.36	35.36	.00	.00
7	10.0	90.0	7.37	9.7	7.37	7.58	1.00	.95	.00	.00
8	7.0	78.0	7.56	7.0	7.56	7.56	10.23	10.23	.00	.00
9	.0	78.0	7.19	.0	7.47	7.19	10.23	8.86	.00	.00
10	210.0	189.0	5.08	208.0	5.99	5.08	24.39	22.97	.00	.00
11	208.0	189.0	1.60	206.0	4.68	1.60	22.97	18.99	.00	.00
12	206.0	125.0	1.60	206.0	1.60	1.60	18.99	18.99	.00	.00
13	206.0	125.0	2.10	205.8	2.10	5.12	18.99	18.80	.00	.00
14	204.0	125.0	3.59	194.2	4.66	3.67	18.80	11.42	.00	.00
15	190.0	140.0	4.34	168.0	4.34	5.67	10.62	6.16	.00	.00
16	170.0	155.0	5.96	168.4	5.96	6.45	5.97	3.94	.00	.00
17	154.0	170.0	5.73	148.0	6.46	5.73	3.99	2.51	.00	.00
18	148.0	194.0	6.03	147.9	6.03	6.16	2.45	2.44	.00	.00
19	147.0	218.0	6.50	145.3	6.50	7.19	2.39	1.91	.00	.00
20	130.0	246.0	7.29	130.0	7.29	7.29	1.87	1.87	.00	.00
21	130.0	270.0	7.40	128.0	7.40	7.64	1.88	1.77	.00	.00

NOT REPRODUCIBLE

*****FINAL SUMMARY*****

SAN ANTONIO RIVER ANALYSIS - DOSAG VERSION

NUMBER OF RUN = 1
TREATMENT (C) = .00
SEASON OF YR. = JUN

TARGET D.O. LEVEL = .01
TREATMENT (N) = .00
MEAN TEMPERATURE =27.50

NO. OF REACH	IDENTIFICATION OF REACH	RIVER MILE TO HEAD OF REACH	REACH LENGTH (MILES)	FLOW RATE (CFS)	D.O. MIN. (MG/L)	RIVER MILE AT MIN. D.O.	DISSOLVED OXYGEN AT START (MG/L)	DISSOLVED OXYGEN AT END (MG/L)
1	SAR HEADWATERS TO RH	232.0	13.0	14.0	7.49	230.7	7.49	7.71
2	RILLING ROAD STP	219.0	.0	111.0	7.09	219.0	7.09	7.09
3	RR STP TO SALADO CRK	219.0	3.0	111.0	6.17	216.0	6.98	6.17
4	SALADO CRK TO CK DAM	216.0	2.0	111.0	.00	214.0	5.31	.00
5	1-MILE BELOW CK DAM	214.0	1.0	111.0	.95	213.9	.95	5.58
6	BELOW DAM TO MEDINA	213.0	3.0	111.0	5.35	210.0	5.55	5.35
7	MEDINA HDWATER TO LC	10.0	3.0	60.6	7.37	9.7	7.37	7.58
8	LEON CREEK STP	7.0	.0	78.0	7.56	7.0	7.56	7.56
9	LEON CRK STP TO SAR	.0	7.0	78.0	7.19	.0	7.47	7.19
10	MR+SAR FOR 3-MI.	210.0	2.0	189.0	5.08	208.0	5.99	5.08
11	ABOVE CALV WITHDRL	208.0	2.0	189.0	1.60	206.0	4.68	1.60
12	CALAVERAS WITHDRAWL	206.0	.0	125.0	1.60	206.0	1.60	1.60
13	CALV WDRL FOR 2-MI.	206.0	2.0	125.0	2.10	205.8	2.10	5.12
14	CALAVERAS TO LOOKF	204.0	14.0	125.0	3.59	194.2	4.66	3.67
15	ELMENDORF TO FLORESF	190.0	20.0	140.0	4.34	168.0	4.34	5.67
16	FLORES TO FALLS CITY	170.0	16.0	155.0	5.96	168.4	5.96	6.45
17	IMPOUNDMENT NR F.C.	154.0	6.0	170.0	5.73	148.0	6.46	5.73
18	FALLS NR F.C.	148.0	1.0	194.0	6.03	147.9	6.03	6.16
19	FALLS CITY TO CIBOLO	147.0	17.0	218.0	6.50	145.3	6.50	7.19
20	CIBOLO CREEK	130.0	.0	246.0	7.29	130.0	7.29	7.29
21	CIBOLO CRK TO KUNGE	130.0	20.0	270.0	7.40	128.0	7.40	7.64

*****FINAL SUMMARY*****

SAN ANTONIO RIVER ANALYSIS - DOSAG VERSION

NUMBER OF RUN = 1
TREATMENT (C) = .00
SEASON OF YR. = JUN

TARGET D.O. LEVEL = .01
TREATMENT (N) = .00
MEAN TEMPERATURE =27.50

NO. OF REACH	IDENTIFICATION OF REACH	CARBONACEOUS BOD AT START (MG/L)	CARBONACEOUS BOD AT END (MG/L)	NITROGENOUS BOD AT START (MG/L)	NITROGENOUS BOD AT END (MG/L)	K2 VALUE BASE E	TRAVEL TIME (DAYS)	MEAN VELOCITY (FPS)	MEAN DEPTH (FT)
1	SAR HEADWATERS TO RR	2.00	1.28	.00	.00	5.941	.966	.81	1.0
2	KILLING ROAD STP	46.12	46.12	.00	.00	.000	.000	.00	2.4
3	RR STP TO SALADO CRK	46.12	44.78	.00	.00	4.799	.065	2.81	3.1
4	SALADO CRK TO CK DAM	44.78	36.71	.00	.00	.157	.440	.28	7.1
5	1-MILE BELOW CK DAM	36.71	36.36	.00	.00	55.000	.022	2.81	3.1
6	BELOW DAM TO MEDINA	36.36	35.30	.00	.00	4.799	.065	2.81	3.1
7	MEDINA NOWATER TO LC	1.00	.93	.00	.00	5.802	.150	1.22	1.4
8	LEON CREEK STP	10.23	10.23	.00	.00	.000	.000	.00	1.5
9	LEON CRK STP TO SAR	10.23	8.86	.00	.00	5.621	.318	1.35	1.6
10	MR+SAR FOR 3-MI.	24.39	22.97	.00	.00	1.166	.133	.92	3.9
11	ABOVE CALV WTHDRL	22.97	18.99	.00	.00	.229	.421	.29	5.5
12	CALAVERAS WITHDRAWL	18.99	18.99	.00	.00	.000	.000	.00	3.5
13	CALV WDRL FOR 2-MI.	18.99	18.80	.00	.00	35.000	.023	5.41	3.2
14	CALAVERAS TO EDORF	18.80	11.42	.00	.00	1.233	1.104	.78	3.2
15	ELMENDORF TO FLORESF	10.62	6.18	.00	.00	1.225	1.537	.80	3.3
16	FLORES TO FALLS CITY	5.97	3.94	.00	.00	1.205	1.176	.83	3.5
17	IMPOUNDMENT NR F.C.	3.95	2.51	.00	.00	.231	1.278	.29	5.4
18	FALLS NR F.C.	2.45	2.44	.00	.00	9.000	.009	7.00	3.8
19	FALLS CITY TO CIBOLO	2.39	1.91	.00	.00	1.557	.805	1.29	4.0
20	CIBOLO CREEK	1.87	1.87	.00	.00	.000	.000	.00	4.2
21	CIBOLO CRK TO KONGE	1.86	1.77	.00	.00	1.510	.863	1.42	4.4

*****FINAL SUMMARY*****

SAN ANTONIO RIVER ANALYSIS - DOSAG VERSION

NUMBER OF RUN = 1
TREATMENT (C) = .00
SEASON OF YR. = JUN

TARGET D.O. LEVEL = .01
TREATMENT (N) = .00
MEAN TEMPERATURE =27.50

NO. OF HEADWATER	NO. OF STRETCH	INITIAL FLOW (CFS)	FINAL FLOW (CFS)	AUGMENTATION REQUIRED (CFS)
1	1	14.0	14.0	.0
2	2	60.6	60.6	.0

PROGRAM LISTINGS

-MAIN PROGRAM-

```
      COMMON CHAIN(50),JUNIT(20),F(16),C(11),IONE(20),G(15),TITLE(20),
     *       IORD(20,20),JUNC(20,3),INIT(16),IAUG(20),DOL(10),IRFAC(10),
     *       CONDZ(20,4),TERMO(12),DATA(50,25),FINIS(50,16),COND(20,4),
     *       IUMCH(20,10),CONDE(20,4),RIDENT(50,5),HWFLO#(10,12),
     *       IRFACN(10),K20PT(50),SEASON(12)
      COMMON JJ,KK,II,D,RMLO#,MAX,CLOW,NTRIB,NREA,NINIT,NJUNC,ELEV,
     *       DOLEV,TF,TEMP,CSAT,M,GUP,FINL,FINC,JA,IA,ICK,FINLN,DELQ,
     *       N1,NJ,K2,VEL,NSEAS,NRUN,IFN
      DIMENSION AMONTH(12)
      REAL  K2
      DATA AMONTH/3HOCT,3HNOV,3HDEC,3HJAN,3HFEB,3HMAR,3HAPR,3HMAY,
     *           3HJUN,3HJUL,3HAUG,3HSEP/
      DATA ENDF/4HENDF/
      N1=5
      NJ=6
      DO 2020 I=1,12
      SEASON(I)=AMONTH(I)
 2020 CONTINUE
      DO 3333 I=1,20
      DO 3333 J=1,3
 3333 CONDZ (I,J)=0.
      DO 40 I=1,20
   40 IAUG(I)=0
      #RITE (6,2055)
 2055 FORMAT (1H1)
C
C                                        STEP-1
C                                        READ AND ECHO WRITE ALL INPUT
C                                        DATA (FILE-A THRU FILE-I).
C
      #RITE (NJ,901)
  901 FORMAT (39X,32H* * * FILE A - BASIN TITLE * * *,///)
      #RITE (NJ,601)
  601 FORMAT (15X,40HCARD                                          NAME,
     *            40H OF                                          #/,
     *        15X,40HTYPE                                       RIVER #
     *            40HBASIN                                        #/)
    1 READ (NI,1) DUM1,DUM2,(TITLE(I),I=1,18)
      #RITE (NJ,737) DUM1,DUM2,(TITLE(I),I=1,18)
    1 FORMAT (20A4)
  737 FORMAT (15X,20A4)
  801 FORMAT (1H0,15X,20A4,///)
      READ (NI,1) DUM1,DUM2
      #RITE (NJ,801) DUM1,DUM2
      IF (DUM1.NE.ENDF) GO TO 777
      #RITE (NJ,902)
  902 FORMAT (35X,41H* * * FILE B - PHYSICAL DESCRIPTION * * *,///)
      #RITE (NJ,602)
  602 FORMAT (15X,40HCARD          NO. OF     NO. OF     NO. OF     NO. ,
     *            40HOF       NO. OF     INSERT 1                MEAN #/,
     *        15X,40HTYPE                HEADWATERS JUNCTIONS  REAC,
     *            40HNES  STRETCHES FOR FINAL                   LLEV.#/,
     *        15X,40H                    MAX OF 10 MAX OF 10 MAX O,
     *            40HF 50 MAX OF 20   SUMMARY                   (FT)#/)
      READ (NI,26) DUM1,DUM2,NINIT,NJUNC,NREA,NTRIB,ICK,ELEV
   26 FORMAT (2A4,5X,I2,5X,4(4X,I2,4X),14X,F6.0)
      #RITE (NJ,804) DUM1,DUM2,NINIT,NJUNC,NREA,NTRIB,ICK,ELEV
  804 FORMAT (15X,2A4,2X,5(5X,I5),14X,F6.1)
      READ (NI,1) DUM1,DUM2
      #RITE (NJ,801) DUM1,DUM2
      IF (DUM1.NE.ENDF) GO TO 777
      #RITE (NJ,904)
  904 FORMAT (39X,32H* * * FILE C - REACH ORDER * * *,///)
      #RITE (NJ,603)
  603 FORMAT (15X,40HCARD          NO. OF                      ORDER OF,
     *            40H ALL REACHES IN EACH STRETCH                 #/,
     *        15X,40HTYPE          STRETCH                      (U,
     *            40HPSTREAM TO DOWNSTREAM)                       #/)
      DO 10 K=1,NTRIB
      READ (NI,3) DUM1,DUM2,I,(IORD(I,J),J=1,20)
    3 FORMAT (2A4,3X,I2,7X,20(1X,I2))
      #RITE (NJ,805) DUM1,DUM2,I,(IORD(I,J),J=1,20)
  805 FORMAT (15X,2A4,2X,I5,5X,20(1X,I2))
   10 CONTINUE
      READ (NI,1) DUM1,DUM2
      #RITE (NJ,801) DUM1,DUM2
      IF (DUM1.NE.ENDF) GO TO 777
      #RITE (NJ,905)
  905 FORMAT (40X,30H* * * FILE D - JUNCTIONS * * *,///)
      #RITE (NJ,604)
  604 FORMAT (15X,40HCARD                              NO.      NO. OF   ,
     *            40H NO. OF     NO. OF      OF      UPSTREAM   #/,
     *        15X,40HTYPE                                        #/,
     *            40HUPSTREAM  DOWNSTREAM  JUNCTION   STRETCH    #/,
     *        15X,40H                                            #/,
     *            40H STRETCH   STRETCH                          #/)
      DO 11 K=1,NJUNC
      READ (NI,33) DUM1,DUM2,I,(JUNC(I,J),J=1,3)
   33 FORMAT (2A4,13X,I2,2X,3(4X,I2,4X))
      WRITE (NJ,806) DUM1,DUM2,I,(JUNC(I,J),J=1,3)
  806 FORMAT (15X,2A4,12X,I5,3(5X,I5))
   11 CONTINUE
      READ (NI,1) DUM1,DUM2
      #RITE (NJ,801) DUM1,DUM2
      IF (DUM1.NE.ENDF) GO TO 777
      #RITE (NJ,906)
  906 FORMAT (40X,31H* * * FILE E - HEADWATERS * * *,///)
      WRITE (NJ,605)
  605 FORMAT (15X,40HCARD                              NO. OF        #N,
     *            40HSERT 1       PERCENT   CARBON.  NITROG.#/,
     *        15X,40HTYPE                    HEADWATER     ,
     *            40H FOR           D.O.      BOD      BOD  #/,
     *        15X,40H                        STRETCH   AUGM,
     *            40HENTATION       SAT.     (MG/L)   (MG/L)#/)
      DO 12 K=1,NINIT
      READ (NI,27) DUM1,DUM2,I,IAUG(I),(CONDZ(I,J),J=1,3)
      INIT(K)=I
   27 FORMAT (2A4,21X,I2,8X,I2,9X,3(2X,F8.0))
      #RITE (NJ,807) DUM1,DUM2,I,IAUG(I),(CONDZ(I,J),J=1,3)
  807 FORMAT (15X,2A4,17X,I5,5X,I10,5X,3(2X,F8.1))
   12 CONTINUE
      READ (NI,1) DUM1,DUM2
      #RITE (NJ,801) DUM1,DUM2
      IF (DUM1.NE.ENDF) GO TO 777
      #RITE (NJ,907)
  907 FORMAT (31X,43H* * * FILE F(1) - DATA(I,1) THRU DATA(I,6) ,
     *            5H* * *,///)
      #RITE (NJ,606)
  606 FORMAT (15X,40HCARD                          NO.  LENGTH OF RIVER M,
     *            40HILE CARBON.   NITROG.    COEF.     EXP. #/,
     *        15X,40HTYPE                          OF    REACH    TO REA,
     *            41HD    REACTION  REACTION ON G FOR  ON G FOR#/,
     *        15X,40H                          REACH   (MILES)  OF REAC,
     *            41HM     COEF.     COEF.    VELOCITY  VELOCITY#/)
      DO 100 K=1,NREA
      READ (NI,105) DUM1,DUM2,I,(DATA(I,J),J=1,6)
  105 FORMAT (2A4,8X,I2,2X,5(2X,F8.0))
      #RITE (NJ,808) DUM1,DUM2,I,(DATA(I,J),J=1,6)
  808 FORMAT (15X,2A4,7X,I5,2(2X,F8.1),4(2X,F8.3))
  100 CONTINUE
      READ (NI,1) DUM1,DUM2
      #RITE (NJ,801) DUM1,DUM2
      IF (DUM1.NE.ENDF) GO TO 777
      #RITE (NJ,908)
  908 FORMAT (31X,44H* * * FILE F(2) - DATA(I,7) THRU DATA(I,14) ,
     *            5H* * *,///)
      #RITE (NJ,607)
  607 FORMAT (15X,40HCARD                          NO.    INCREMENTAL (R,
     *            42HUNOFF) FLOWS   SEWAGE AND INDUSTRIAL FLOWS#/,
     *        15X,40HTYPE                          OF      FLOW   DISS. CA,
     *            43HRBON. NITROG.  FLOW   DISS. CARBON. NITROG.#/,
     *        15X,40H                          REACH    RATE   OXYGEN    ,
     *            40HBOD     BOD    RATE   OXYGEN    BOD      BOD#/)
      DO 150 K=1,NREA
      READ (NI,140) DUM1,DUM2,I,(DATA(I,J),J=7,14)
  140 FORMAT (2A4,8X,I2,2X,2(2X,F7.0,2X,F5.0,2X,F5.0,2X,F5.0))
      #RITE (NJ,809) DUM1,DUM2,I,(DATA(I,J),J=7,14)
  809 FORMAT (15X,2A4,7X,I5,2(2X,F7.1,2X,F5.1,2X,F5.1,2X,F5.1))
  150 CONTINUE
      READ (NI,1) DUM1,DUM2
      #RITE (NJ,801) DUM1,DUM2
      IF (DUM1.NE.ENDF) GO TO 777
      #RITE (NJ,909)
  909 FORMAT (30X,40H* * * FILE F(3) - DATA(I,15) THRU DATA (I,20) ,
     *            5H* * *,///)
      #RITE (NJ,608)
  608 FORMAT (15X,40HCARD                          NO.    VALUE   COEF. O,
     *            41HN    EXP. ON   EXP. ON  COEF. ON   EXP. ON#/,
     *        15X,40HTYPE                          OF     FOR K2   V FOR K,
     *            41H2   V FOR K2  D FOR K2  Q FOR K2  Q FOR K2#/,
     *        15X,40H                          REACH   OPTION-1 OPTION-,
     *            41H2   OPTION-2  OPTION-2  OPTION-3  OPTION-3,/)
      DO 160 K=1,NREA
      READ (NI,170) DUM1,DUM2,I,(DATA(I,J),J=15,20)
  170 FORMAT (2A4,8X,I2,2X,6(2X,F8.0))
      #RITE (NJ,810) DUM1,DUM2,I,(DATA(I,J),J=15,20)
  810 FORMAT (15X,2A4,7X,I5,6(2X,F8.3))
  160 CONTINUE
      READ (NI,1) DUM1,DUM2
      #RITE (NJ,801) DUM1,DUM2
      IF (DUM1.NE.ENDF) GO TO 777
      #RITE (NJ,910)
  910 FORMAT (30X,45H* * * FILE F(4) - DATA(I,21) THRU DATA(I,23) ,
     *            5H* * *,///)
      #RITE (NJ,609)
  609 FORMAT (15X,40HCARD                          NO.  OPTION          NA,
     *            40HME                      COEF.    EXP.    CHANNEL#/,
     *        15X,40HTYPE                          OF     FOR       O,
     *            40HF                     ON Q FOR  ON Q FOR   SLOPE #/,
     *        15X,40H                          REACH    K2        KEA,
     *            41HCH                    DEPTH     DEPTH   OPTION-4,/)
      DO 230 K=1,NREA
      READ (NI,240) DUM1,DUM2,I,K20PT(I),(RIDENT(I,J),J=1,5),
     *              (DATA(I,J),J=21,23)
  240 FORMAT (2A4,6X,I2,6X,I2,4X,5A4,3(2X,F8.0))
      #RITE (NJ,811) DUM1,DUM2,I,K20PT(I),(RIDENT(I,J),J=1,5),
     *              (DATA(I,J),J=21,23)
  811 FORMAT (15X,2A4,7X,I5,4X,I2,4X,5A4,3(2X,F8.3))
  230 CONTINUE
      READ (NI,1) DUM1,DUM2
      #RITE (NJ,801) DUM1,DUM2
      IF (DUM1.NE.ENDF) GO TO 777
      WRITE (NJ,911)
```


NOT REPRODUCIBLE

```
911 FORMAT (34X,42H* * * FILE G - BASIN CHARACTERISTICS * * *,//)
    WRITE (NJ,610)
610 FORMAT (15X,40HCARD                          MINIMUM ALLOWABLE      ,
   *        40H      PERCENT TREATMENT (M + I FLOWS)    ,/,
   *        15X,40HTYPE                        D.O. LEVEL (MG/L)      ,
   *        40H CAR  NIT  CAR  NIT  CAR  NIT  CAR  NIT  CAR  NIT ,/)
    READ (NI,5) DUM1,DUM2,(DOL(I),I=1,4),(TRFAC(I),TRFACN(I),I=1,4)
  5 FORMAT (2A4,7X,4F5.0,5X,8F5.0)
    WRITE (NJ,812) DUM1,DUM2,(DOL(I),I=1,4),(TRFAC(I),TRFACN(I),I=1,4)
612 FORMAT (15X,2A4,7X,4F5.1,5X,8F5.1)
    READ (NI,1) DUM1,DUM2
    WRITE (NJ,801) DUM1,DUM2
    IF (DUM1.NE.ENDF) GO TO 777
    WRITE (NJ,912)
912 FORMAT (32X,46H* * * FILE H - MEAN MONTHLY TEMPERATURES * * *,//)
    WRITE (NJ,611)                                        STREAM TEM,
611 FORMAT (15X,40HCARD
   *        40HPERATURE IN DEGREES CENTIGRADE                    ,//,
   *        15X,40HTYPE                        OCT  NOV  DEC  JAN,
   *        40H  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP,/)
    READ (NI,6) DUM1,DUM2,(TEMMO(I),I=1,12)
  6 FORMAT (2A4,12X,12F5.0)
    WRITE (NJ,813) DUM1,DUM2,(TEMMO(I),I=1,12)
813 FORMAT (15X,2A4,12X,12F5.1)
    READ (NI,1) DUM1,DUM2
    WRITE (NJ,801) DUM1,DUM2
    IF (DUM1.NE.ENDF) GO TO 777
    WRITE (NJ,913)
913 FORMAT (31X,44H* * * FILE I - MEAN MONTHLY HEADWATER FLOWS ,
   *        5H* * *,//)
    WRITE (NJ,612)                                          ,
612 FORMAT (15X,40HCARD          NO. OF                     ,//,
   *        40HHEADWATER FLOWS IN CFS                      ,
   *        15X,40HTYPE        HEADWATER   OCT  NOV  DEC  JAN,
   *        40H  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP,/)
    DO 250 K=1,NINIT
    READ (NI,260) DUM1,DUM2,I,(HWFLOW(I,J),J=1,12)
260 FORMAT (2A4,3X,I2,7X,12F5.0)
    WRITE (NJ,270) DUM1,DUM2,I,(HWFLOW(I,J),J=1,12)
270 FORMAT (15X,2A4,2X,I5,5X,12F5.1)
250 CONTINUE
    READ (NI,1) DUM1,DUM2
    WRITE (NJ,801) DUM1,DUM2
    IF (DUM1.NE.ENDF) GO TO 777
    DO 25 L=1,NINIT
    CONDZ(L,1)=CONDZ(L,1)/100.0
 25 CONTINUE
    NRUN=0

C                                          STEP-2
C                                          SET BASIN CONDITIONS TO BE
C                                          CONSIDERED (TARGET D.O. LEVEL,
C                                          TREATMENT EFF., AND TEMPERATURE).
C

    DO 13 I=1,4
    IF (DOL(I))20,13,20
 20 DOLEV=DOL(I)
    DO 14 J=1,4
    IF (TRFAC(J)+TRFACN(J))21,14,21
 21 TF=TRFAC(J)/100.0
    TFN=TRFACN(J)/100.0
    DO 15 K=1,12
    IF (TEMMO(K))22,15,22
 22 TEMP=TEMMO(K)
    NSEAS=K
    DO 24 L=1,NINIT
    CONDZ(L,4)=HWFLOW(L,K)
 24 CONTINUE
    IF (ICK)3335,3335,3336
3335 WRITE (NJ,2055)
    WRITE (NJ,334)
 334 FORMAT (26X,49H* * * * * I N T E R M E D I A T E  S U M M A R Y,
   *        10H * * * * *,//)
    WRITE (NJ,8011) (TITLE(L),L=1,18)
6011 FORMAT (19X,18A4,///)
    NRUN=NRUN+1
    WRITE (NJ,335) NRUN,DOLEV,TF,TFN,SEASON(NSEAS),TEMP
 335 FORMAT (15X,15HNUMBER OF RUN =,  I5,36X,19HTARGET D.O. LEVEL =,
   *        F5.2,/,
   *        15X,15HTREATMENT (C) =,F5.2,36X,19HTREATMENT (N)     =,
   *        F5.2,/,
   *        15X,17HSEASON OF YR. =  ,A3,36X,19HMEAN TEMPERATURE  =,
   *        F5.2,//)
```

NOT REPRODUCIBLE

```
C                                          STEP-3
C                                          CALL  R U N O N
C
C
C
C
 3336 CALL RUNON
C
C                                          STEP-4
C                                          REPEAT STEP-2 THRU STEP-3
C                                          UNTIL ALL COMBINATIONS OF
C                                          BASIN CONDITIONS HAVE BEEN
C                                          ANALYZED.
C
C
C
   15 CONTINUE
   14 CONTINUE
   13 CONTINUE
      GO TO 7777
  777 WRITE (NJ,778)
  778 FORMAT (1H1,21X,34H* * * * * * * * * * * * * * * * * * * * *,//,
     *        33H* * * * * * * * * * * * * * * * * * * *,/,
     *        22X,34H* E X E C U T I O N  W A S  T E *,///,
     *        33HR M I N A T E D  B E C A U S E *,///,
     *        22X, 1H*,31X,3HO F,31X,1H*,//,
     *        22X,34H*        E R R O R S  I N        *,///,
     *        22X,34H*  I N P U T  D A T A            *,/,
     *        22X,34H* * * * * * * * * * * * * * * * * * * * *)
      GO TO 9999
 7777 CONTINUE
 9999 CONTINUE
      STOP
      END
```

-SUBROUTINE RUNON-

```
      SUBROUTINE RUNON
      COMMON CRMIN(50),UNIT(20),F(10),C(11),IONE(20),G(15),TITLE(20),
     *       IORD(20,20),JUNC(20,3),IGIT(10),IAUG(20),DOL(10),TRFAC(10),
     *       CONDZ(20,4),TEMPO(12),DATA(50,25),FINIS(50,16),CONDI(20,4),
     *       IDMCH(20,10),CONDE(20,4),RIDENT(50,5),HWFLOW(10,12),
     *       TRFACN(10),A20PT(50),SEASON(12)
      COMMON JJ,KK,II,JJ,KKLOW,NAX,CLOW,NTRIB,NREA,NINIT,NJUNC,ELEV,
     *       DOLEV,TF,TEMP,CSAT,MAXUP,FINL,FINC,JA,IA,ICK,FINLN,DELJ,
     *       NI,NJ,K2,VEL,NSEAS,NRUN,TFN
      REAL  K2

C                                          STEP-1
C                                          SET ALL HEADWATER CONDITIONS
C                                          EQUAL TO ZERO.
      DO 1 I=1,20
      DO 1 J=1,4
    1 CONDI(I,J)=CONDZ (I,J)

C                                          STEP-2
C                                          CALL  D O S A T
      CALL DOSAT

C                                          STEP-3
C                                          CALCULATE D.O. LEVEL FOR ALL
C                                          HEADWATER STRETCHES.
      DO 2 I=1,20
    2 CONDI(I,1)=CONDI(I,1)*CSAT
      M=0
      IF(ICK)3335,3335,3333

C                                          STEP-4
C                                          WRITE HEADING FOR INTERMEDIATE
C                                          REACH SUMMARY.
 3335 WRITE (NJ,386)
  386 FORMAT (1H0)
      WRITE (NJ,333)
  333 FORMAT ( 7X,48H NO.  RIVER MILE  FLOW    D.O.  RIVER MILE  DISS,
     *          48HOLVED OXYGEN  CARBONACEOUS BOD  NITROGENOUS  BOD,/,
     *        7X,48H OF      TO HEAD   RATE     MIN.     AT MIN.    AT S,
     *          48HTART  AT END  AT START  AT END  AT START  AT END,/,
     *        7X,48HREACH   OF REACH   (CFS)  (MG/L)     D.O.       (MG,
     *          48H/L)    (MG/L)     (MG/L)   (MG/L)    (MG/L)    (MG/L),/,
     *        7X,48H----- ---------  -----  ------ ----------  -----
     *          46H-----  ------  --------  ------  --------  -------/)

C                                          STEP-5
C                                          CALL  R E I N I
C
 3333 CALL REINI
      IF(M)4,4,3

C                                          STEP-6
C                                          CALL  R M A T C
C
    4 CALL RMATC
      IF(M)5,5,3

C                                          STEP-7
C                                          WRITE HEADING FOR FINAL
C                                          SUMMARY.
C
    5 WRITE (NJ,2055)
 2055 FORMAT (1H1)
      WRITE (NJ,24)
   24 FORMAT (33X,45H* * * * F I N A L  S U M M A R Y * * * *,//)
      WRITE (NJ,336) (TITLE(I),I=1,18)
  336 FORMAT (19X,18A4,//)
      WRITE (NJ,335) NRUN,DOLEV,TF,TFN,SEASON(NSEAS),TEMP
  335 FORMAT (15X,13HNUMBER OF RUN =,  I5,36X,19HTARGET D.O. LEVEL =,
     *          F5.2,/,
     *        15X,13HTREATMENT (C) =,F5.2,36X,19HTREATMENT (N)     =,
     *          F5.2,/,
     *        15X,17HSEASON OF YR. =  ,A3,36X,19HMEAN TEMPERATURE  =,
     *          F5.2,//)
      WRITE (NJ,25)
   25 FORMAT (10X,45H NO.      IDENTIFICATION     RIVER MILE  REACH ,/,
     *          45H  FLOW     D.O.  RIVER MILE  DISSOLVED OXYGEN ,/,
     *        10X,43H OF          OF             TO HEAD   LENGTH ,/,
     *          45H  RATE     MIN.     AT MIN.   AT START  AT END ,/,
     *        10X,45HREACH        REACH          OF REACH  (MILES),/,
     *          45H  (CFS)  (MG/L)     D.O.       (MG/L)    (MG/L) ,/,
     *        10X,43H----- -------------------- ---------- --------,
     *          45H  -----  ------ ----------  ---------  ------ /)
```

NOT REPRODUCIBLE

```
C                                          STEP-8
C                                          WRITE FINAL SUMMARY.
      DO 89 I=1,NREA
      IF(FINIS(I,1)
      WRITE (NJ,28) IR,(RIDENT(I,J),J=1,5),(FINIS(I,J),J=2,6),
     *              FINIS(I,14),FINIS(I,7)
   89 CONTINUE
   28 FORMAT (10X,I3,3X,5A4,2X,F7.1,4X,F5.1,1X,F7.1,2X,F5.2,3X,F7.1,
     *        5X,F5.2,4X,F5.2)
      WRITE (NJ,2055)
      WRITE (NJ,24)
      WRITE (NJ,336) (TITLE(I),I=1,18)
      WRITE (NJ,335) NRUN,DOLEV,TF,TFN,SEASON(NSEAS),TEMP
      WRITE (NJ,30)
   30 FORMAT ( 8X,47H NO.      IDENTIFICATION     CARBONACEOUS BOD  NI,
     *          47HTROGENOUS  BOD    K2     TRAVEL    MEAN     MEAN ,/,
     *        8X,47H OF          OF                    AT START  AT END  AT,
     *          47H START  AT END  VALUE     TIME    VELOCITY  DEPTH,/,
     *        8X,47HREACH        REACH          (MG/L)    (MG/L)    (,
     *          47HMG/L)   (MG/L) BASE E  (DAYS)    (FPS)     (FT) ,/,
     *        8X,47H----- -------------------- --------  ------  ------ ,/,
     *          47H-----  ------- -------  ------  --------  ------/)
      DO 89 I=1,NREA
      IF(FINIS(I,1)
      WRITE (NJ,32) IR,(RIDENT(I,J),J=1,5),FINIS(I,15),FINIS(I,11),
     *              FINIS(I,16),FINIS(I,12),(FINIS(I,J),J=8,10),
     *              FINIS(I,13)
   89 CONTINUE
   32 FORMAT ( 8X,I3,3X,5A4,1X,F6.2,3X,F6.2,3X,F6.2,3X,F6.2,1X,F7.3,
     *        2X,F7.3,2X,F6.2,3X,F5.1)
      WRITE (NJ,2055)
      WRITE (NJ,24)
      WRITE (NJ,336) (TITLE(I),I=1,18)
      WRITE (NJ,335) NRUN,DOLEV,TF,TFN,SEASON(NSEAS),TEMP
      WRITE (NJ,55)
   55 FORMAT (31X,48H  NO.       NO.    INITIAL  FINAL  AUGMENTATION,/,
     *        31X,48H  OF        OF      FLO#     FLO#    REQUIRED  ,/,
     *        31X,48HHEADWATER  STRETCH   (CFS)    (CFS)     (CFS)    ,/,
     *        31X,48H---------  -------  -------  -----  ------------/)
      DO 100 I=1,NINIT
      GAUG=CONDI(I,4)-CONDZ(I,4)
      WRITE (NJ,56) I,INIT(I),CONDZ(I,4),CONDI(I,4),GAUG
   56 FORMAT (31X,I5,5X,I5,4X,F7.1,1X,F7.1,3X,F7.1)
  100 CONTINUE

C                                          STEP-9
C                                          RETURN TO CALLER (D O S A G).
      RETURN
      END
```

-SUBROUTINE REINI-

```
      SUBROUTINE RLINI
      COMMON CHMIN(50),UNIT(20),F(10),C(11),IONE(20),G(15),TITLE(20),
     *       IORD(20,20),JUNC(20,3),INIT(10),IAUG(20),LOL(10),TRFAC(10),
     *       CONDZ(20,4),TEMMO(12),DATA(50,25),FINIS(50,16),CONDI(20,4),
     *       IUMCH(20,10),CONDE(20,4),NIDENT(50,5),HWFLOW(10,12),
     *       TRFACN(10),K2OPT(50),SEASON(12)
      COMMON JJ,KK,II,D,RMLOW,MAX,CLOW,NTRIB,NREA,NINIT,NJUNC,ELEV,
     *       DOLEV,TF,TEMP,CSAT,M,GUP,FINL,FINC,JA,IA,ICK,FINLN,DELQ,
     *       NI,NJ,K2,VEL,NSEAS,NRUN,TFN
      REAL  K2
C
C                                     STEP-1
C                                     SET MACHINE IDENTIFIERS FOR
C                                     COUNTING UPSTREAM AUGMENTATION.
C
      DO 1 I=1,NINIT
      JA=INIT(I)
      IF(IAUG(JA))2,2,3
    3 IUMCH(JA,1)=JA
      IUMCH(JA,2)=0
      GO TO 4
    2 IUMCH(JA,1)=0
C
C
C                                     STEP-2
C                                     SET INITIAL CONDITIONS OF
C                                     STRETCH EQUAL TO FINAL
C                                     CONDITIONS OF PRECEDING
C                                     STRETCH.
C
    4 GUP=CONDI(JA,4)
      FINLN=CONDI(JA,3)
      FINL=CONDI(JA,2)
      FINC=CONDI(JA,1)
C
C                                     STEP-3
C                                     CALL  T R I B D
C
      CALL TRIBD
C
C                                     STEP-4
C                                     CALL  S C A N
C
      CALL SCAN
C
C                                     STEP-5
C                                     SET FINAL CONDITIONS TO
C                                     CALCULATED CONDITIONS
C
      CONDE(JA,3)=FINLN
      CONDE(JA,4)=GUP
      CONDE(JA,2)=FINL
      CONDE(JA,1)=FINC
C
C                                     STEP-6
C                                     REPEAT STEP-1 THRU STEP-5 FOR
C                                     EACH HEADWATER STRETCH.
C
      IF(M)1,1,5
    1 CONTINUE
C
C                                     STEP-7
C                                     RETURN TO CALLER (R U N O N).
C
    5 RETURN
      END
```

NOT REPRODUCIBLE

-SUBROUTINE RMATC-

```
      SUBROUTINE RMATC
      COMMON CHMIN(50),UNIT(20),F(10),C(11),IONE(20),G(15),TITLE(20),
     *       IORD(20,20),JUNC(20,3),INIT(10),IAUG(20),LOL(10),TRFAC(10),
     *       CONDZ(20,4),TEMMO(12),DATA(50,25),FINIS(50,16),CONDI(20,4),
     *       IUMCH(20,10),CONDE(20,4),NIDENT(50,5),HWFLOW(10,12),
     *       TRFACN(10),K2OPT(50),SEASON(12)
      COMMON JJ,KK,II,D,RMLOW,MAX,CLOW,NTRIB,NREA,NINIT,NJUNC,ELEV,
     *       DOLEV,TF,TEMP,CSAT,M,GUP,FINL,FINC,JA,IA,ICK,FINLN,DELQ,
     *       NI,NJ,K2,VEL,NSEAS,NRUN,TFN
      REAL  K2
C
C                                     STEP-1
C                                     FIND THE HEADWATER STRETCHES
C                                     THAT ENTER A JUNCTION.
C
      DO 1 I=1,20
    1 IONE(I)=0
      IF(NJUNC)333,333,334
  333 IONE(1)=1
  334 DO 2 I=1,20
    2 UNIT(I)=0
      IINIT=NINIT
      DO 3 I=1,IINIT
      UNIT(I)=INIT(I)
      J=INIT(I)
    3 IONE(J)=1
   10 DO 4 I=1,NJUNC
      DO 5 J=1,IINIT
      IF(JUNC(I,1)-UNIT(J))5,6,5
    5 CONTINUE
      GO TO 4
    6 DO 7 J=1,IINIT
      IF(JUNC(I,2)-UNIT(J))7,8,7
    7 CONTINUE
      GO TO 4
    8 II=JUNC(I,1)
      JJ=JUNC(I,2)
      KK=JUNC(I,3)
      JA=KK
      IAUG(KK)=1
C
C                                     STEP-2
C                                     CALL  B L E N D
C
      CALL BLEND
      FINLN=CONDI(KK,3)
      GUP=CONDI(KK,4)
      FINL=CONDI(KK,2)
      FINC=CONDI(KK,1)
C
C                                     STEP-3
C                                     SET MACHINE IDENTIFIERS TO
C                                     INDICATE THE NUMBER OF SOURCES
C                                     OF AUGMENTATION UPSTREAM.
C
      L=1
      LL=1
   13 IF(IUMCH(JJ,L))9,9,10
   10 IUMCH(KK,L)=IUMCH(JJ,L)
      L=L+1
    9 IF(IUMCH(II,LL))11,11,12
   12 IUMCH(KK,L)=IUMCH(II,LL)
      LL=LL+1
      L=L+1
      GO TO 9
   11 IUMCH(KK,L)=0
C
C                                     STEP-4
C                                     CALL  T R I B D
C
      CALL TRIBD
C
C                                     STEP-5
C                                     CALL  S C A N
C
      CALL SCAN
C
C                                     STEP-6
C                                     SET FINAL CONDITIONS EQUAL
C                                     TO CALCULATED CONDITIONS
C
      CONDE(JA,1)=FINC
      CONDE(JA,2)=FINL
      CONDE(JA,3)=FINLN
      CONDE(JA,4)=GUP
C
C                                     STEP-7
C                                     REPEAT STEP-1 THRU STEP-6
C                                     UNTIL ALL JUNCTIONS HAVE BEEN
C                                     CONSIDERED.
C
      IF(M)14,14,15
   14 IONE(KK)=1
      IINIT=IINIT+1
      UNIT(IINIT)=KK
    4 CONTINUE
      DO 17 I=1,NTRIB
      IF(IONE(I))16,16,17
   17 CONTINUE
C
C                                     STEP-8
C                                     RETURN TO CALLER (R U N O N).
C
   15 RETURN
      END
```

-SUBROUTINE TRIBD-

```
      SUBROUTINE TRIBD
      COMMON CRMIN(50),JNIT(20),F(10),C(11),IONE(20),G(15),TITLE(20),
     *       IORD(20,20),JUNC(20,3),INIT(10),IAUG(20),VOL(10),TRFAC(10),
     *       CONDZ(20,4),TEMMO(12),DATA(50,25),FINIS(50,16),CONDI(20,4),
     *       IDMCH(20,10),CONDE(20,4),KIDENT(50,5),HWFLOW(10,12),
     *       TRFACN(10),K2OPT(50),SEASON(12)
      COMMON JJ,KK,II,B,RMLOW,MAX,CLOW,NTRIB,NREA,NINIT,NJUNC,ELEV,
     *       DOLEV,TF,TEMP,CSAT,M,QUP,FINL,FINC,JA,IA,ICK,FINLN,DELQ,
     *       NI,NJ,K2,VEL,NSEAS,NRUN,TFN
      REAL  K2
C
C                                     STEP-1
C                                     CHECK TO SEE IF THERE ARE ANY
C                                     DOWNSTREAM REACHES TO BE
C                                     CONSIDERED IN THE STRETCH.
      I=1
      IF(IORD(JA,I))1,1,3
C
C                                     STEP-2
C                                     CONSIDER NEXT DOWNSTREAM
C                                     REACH.
    3 IA=IORD(JA,I)
C
C                                     STEP-3
C                                     CALL  R E P R E
      CALL REPRE
C
C                                     STEP-4
C                                     CALL  D O E Q U
      CALL DOEQU
      QUP=G(2)
      IF(QUP) 10,10,20
C
C                                     STEP-5
C                                     STORE MINIMUM DISSOLVED OXYGEN
C                                     OF REACH.
   10 CRMIN(IA)=CONDI(JA,1)
      GO TO 30
   20 CRMIN(IA)=CLOW
   30 CONTINUE
      I=I+1
C
C                                     STEP-6
C                                     REPEAT STEP-1 THRU STEP-5
C                                     UNTIL ALL REACHES HAVE BEEN
C                                     CONSIDERED.
C
      GO TO 2
C
C                                     STEP-7
C                                     RETURN TO CALLER (R E I N I)
C                                     OR (R M A T C).
    1 RETURN
      END
```


-SUBROUTINE SCAN-

```
      SUBROUTINE SCAN
      COMMON CRMIN(50),JNIT(20),F(10),C(11),IONE(20),G(15),TITLE(20),
     *       IORD(20,20),JUNC(20,3),INIT(10),IAUG(20),VOL(10),TRFAC(10),
     *       CONDZ(20,4),TEMMO(12),DATA(50,25),FINIS(50,16),CONDI(20,4),
     *       IDMCH(20,10),CONDE(20,4),KIDENT(50,5),HWFLOW(10,12),
     *       TRFACN(10),K2OPT(50),SEASON(12)
      COMMON JJ,KK,II,B,RMLOW,MAX,CLOW,NTRIB,NREA,NINIT,NJUNC,ELEV,
     *       DOLEV,TF,TEMP,CSAT,M,QUP,FINL,FINC,JA,IA,ICK,FINLN,DELQ,
     *       NI,NJ,K2,VEL,NSEAS,NRUN,TFN
      REAL  K2
C
C                                     STEP-1
C                                     CHECK FOR AVAILABLE
C                                     AUGMENTATION.
      I=0
      IF(IAUG(JA))1,1,2
    2 I=I+1
C
C                                     STEP-2
C                                     CHECK FOR REACHES IN A
C                                     STRETCH.
      IF(IORD(JA,I))1,1,3
    3 IA=IORD(JA,I)
C
C                                     STEP-3
C                                     CALCULATE D.O. DEFICIT FOR
C                                     REACH.
      Z=DOLEV -CRMIN(IA)
      IF(Z-.05)2,2,5
    4 CONTINUE
C
C                                     STEP-4
C                                     CALCULATE AMOUNT OF DILUTION
C                                     WATER NEEDED TO SATISFY THE
C                                     DEFICIT.
    5 QADD=QUP*(Z/DOLEV + 0.25*(Z/DOLEV)**2)
C
C                                     STEP-5
C                                     CHECK TO SEE HOW MANY UPSTREAM
C                                     SOURCES OF AUGMENTATION ARE
C                                     AVAILABLE.
      L=1
      LL=0
      M=1
    7 IF(IDMCH (JA,L))1,8,6
    6 LL=LL+1
      L=L+1
      GO TO 7
    8 W=LL
C
C                                     STEP-6
C                                     DIVIDE DILUTION WATER EQUALLY
C                                     AMONG ALL SOURCES OF
C                                     AUGMENTATION.
      QPLUS=QADD/W
      L=1
   10 IF(IDMCH (JA,L))1,1,9
C
C                                     STEP-7
C                                     ADD DILUTION WATER TO UPSTREAM
C                                     AUGMENTATION SOURCES.
    9 IB=IDMCH (JA,L)
      CONDI(IB,4)=CONDI(IB,4)+(.5*QPLUS)
   12 L=L+1
      GO TO 10
C
C                                     STEP-8
C                                     RETURN TO CALLER (R M A T C)
C                                     OR (R E I N I).
    1 RETURN
      END
```

-SUBROUTINE DOSAT-

```
      SUBROUTINE DOSAT
      COMMON CRMIN(50),JNIT(20),F(10),C(11),IONE(20),G(15),TI LE(20),
     *       IORD(20,20),JUNC(20,3),INIT(10),IAUG(20),DOL(10) TRFAC(10),
     *       COND2(20,4),TEMMO(12),DATA(50,25),FINIS(50,16),COND1(20,4),
     *       IDMCH(20,10),CONDE(20,4),HIDENT(50,5),HWFLOW(10, 2),
     *       TRFACN(10),K2OPT(50),SEASON(12)
      COMMON JJ,KK,II,O,RMLOW,MAX,CLOW,NTRIB,NREA,NINIT,NJUNC ELEV,
     *       DOLEV,TF,TEMP,CSAT,M,QUP,FINL,FINC,JA,IA,ICK,FIN N,DELQ,
     *       NI,NJ,K2,VEL,NSEAS,NRUN,TFN
      REAL  K2
C
C                                     STEP-1
C                                     CALCULATE THE D.O. SATURATION
C                                     LEVEL FROM TEMPERATURE AND
C                                     BASIN ELEVATION.
C
      CSAT=(14.62-(.3898*TEMP)+(.006964*TEMP**2)-(.00005897*T MP**3))*(
     *     (1.0-(0.00000697*ELEV))**5.167)
C
C                                     STEP-2
C                                     RETURN TO CALLER (N U N O N).
C
      RETURN
      END
```

-SUBROUTINE CHKPO-

```
      SUBROUTINE CHKPO
      COMMON CRMIN(50),JNIT(20),F(10),C(11),IONE(20),G(15),TITLE(20),
     *       IORD(20,20),JUNC(20,3),INIT(10),IAUG(20),DOL(10),TRFAC(10),
     *       COND2(20,4),TEMMO(12),DATA(50,25),FINIS(50,16),COND1(20,4),
     *       IDMCH(20,10),CONDE(20,4),HIDENT(50,5),HWFLOW(10,12),
     *       TRFACN(10),K2OPT(50),SEASON(12)
      COMMON JJ,KK,II,O,RMLOW,MAX,CLOW,NTRIB,NREA,NINIT,NJUNC,ELEV,
     *       DOLEV,TF,TEMP,CSAT,M,QUP,FINL,FINC,JA,IA,ICK,FINLN,DELQ,
     *       NI,NJ,K2,VEL,NSEAS,NRUN,TFN
      REAL  K2
C
C                                     STEP-1
C                                     CALCULATE THE EXPONENTIAL
C                                     FUNCTION (EXP(X)).
C
      I=0
      B=B-.000001
    3 IF(B+(10.**(-I)))2,2,1
    1 I=I+1
      GO TO 3
    2 BA=(10.**I)*B
      BB=BA-B
      BC=EXP(BA)
      BD=EXP(BB)
      H=BC/BD
C
C                                     STEP-2
C                                     RETURN TO CALLER (D O E Q U).
C
      RETURN
      END
```

-SUBROUTINE REPRE-

```
      SUBROUTINE REPRE
      COMMON CRMIN(50),JNIT(20),F(10),C(11),IONE(20),G(15),TITLE(20),
     *       IORD(20,20),JUNC(20,3),INIT(10),IAUG(20),DOL(10),TRFAC(10),
     *       COND2(20,4),TEMMO(12),DATA(50,25),FINIS(50,16),COND1(20,4),
     *       IDMCH(20,10),CONDE(20,4),HIDENT(50,5),HWFLOW(10,12),
     *       TRFACN(10),K2OPT(50),SEASON(12)
      COMMON JJ,KK,II,O,RMLOW,MAX,CLOW,NTRIB,NREA,NINIT,NJUNC,ELEV,
     *       DOLEV,TF,TEMP,CSAT,M,QUP,FINL,FINC,JA,IA,ICK,FINLN,DELQ,
     *       NI,NJ,K2,VEL,NSEAS,NRUN,TFN
      REAL  K2
C
C                                     STEP-1
C                                     MAKE ALL INITIAL CALCULATIONS
C                                     FOR REACH D.O. CALCULATIONS.
C
      G(1)=DATA(IA,3)*1.047**(TEMP-20.0)
      G(2)=QUP+DATA(IA,7)+DATA(IA,11)
      G(5)=DATA(IA,2)
      G(7)=TEMP
      G(9)=CSAT
      G(10)=DATA(IA,1)
      G(11)=DATA(IA,4)*1.047**(TEMP-20.0)
      IF(DATA(IA,11)) 1,2,1
    1 G(6)=((QUP*FINL)+(DATA(IA,7)*DATA(IA,9))
     *     +(DATA(IA,11)*FINL))/G(2)
      G(8)=((QUP*FINC)+(DATA(IA,7)*DATA(IA,8))
     *     +(DATA(IA,11)*FINC))/G(2)
      G(12)=((QUP*FINLN)+(DATA(IA,7)*DATA(IA,10))
     *     +(DATA(IA,11)*FINLN))/G(2)
      GO TO 3
    2 G(6)=((QUP*FINL)+(DATA(IA,7)*DATA(IA,9))+(DATA(IA,11)*DATA(IA,13)*
     1(1.0-TF)))/G(2)
      G(8)=((FINC*QUP)+(DATA(IA,7)*DATA(IA,8))+(DATA(IA,11)*DATA(IA,12))
     1)/G(2)
      G(12)=((QUP*FINLN)+(DATA(IA,7)*DATA(IA,10))+(DATA(IA,11)*DATA(IA,1
     14)*(1.0-TFN)))/G(2)
    3 CONTINUE
C
C                                     STEP-2
C                                     RETURN TO CALLER (T H I S D).
C
      RETURN
      END
```

-SUBROUTINE BLEND-

```
      SUBROUTINE BLEND
      COMMON CRMIN(50),JNIT(20),F(10),C(11),IONE(20),G(15),TITLE(20),
     *       IORD(20,20),JUNC(20,3),INIT(10),IAUG(20),DOL(10) TRFAC(10),
     *       COND2(20,4),TEMMO(12),DATA(50,25),FINIS(50,16),COND1(20,4),
     *       IDMCH(20,10),CONDE(20,4),HIDENT(50,5),HWFLOW(10,12),
     *       TRFACN(10),K2OPT(50),SEASON(12)
      COMMON JJ,KK,II,O,RMLOW,MAX,CLOW,NTRIB,NREA,NINIT,NJUNC,ELEV,
     *       DOLEV,TF,TEMP,CSAT,M,QUP,FINL,FINC,JA,IA,ICK,FINLN,DELQ,
     *       NI,NJ,K2,VEL,NSEAS,NRUN,TFN
      REAL  K2
C
C                                     STEP-1
C                                     ADD TWO UPSTREAM FLOWS AT A
C                                     JUNCTION TO GET DOWNSTREAM
C                                     FLOW.
C
      COND1(KK,4)=CONDE(JJ,4)+CONDE(II,4)
C
C                                     STEP-2
C                                     CALCULATE DOWNSTREAM BOD AND
C                                     D.O. BY USING A WEIGHTED MASS
C                                     BALANCE FORMULA.
C
      DO 3 I=1,3
      COND1(KK,I)=((CONDE(JJ,4)*CONDE(JJ,I))+(CONDE(II,4)*CONDE(II,I)))
     1/COND1(KK,4)
    3 CONTINUE
C
C                                     STEP-3
C                                     RETURN TO CALLER (R H A T C)
C
      RETURN
      END
```

-SUBROUTINE DOEQU-

```
      SUBROUTINE DOEQU
      COMMON CRMIN(50),UNIT(20),F(10),C(11),IONE(20),G(15),TITLE(20),
     *       IORD(20,20),JUNC(20,3),IMIT(10),IAUG(20),LOL(10),TRFAC(10),
     *       COND2(20,4),TEMMO(12),DATA(50,25),FINIS(50,16),LOWDI(20,4),
     *       IDMCH(20,10),CONDE(20,4),RIDENT(50,5),HWFLOW(10,12),
     *       TRFACM(10),K2OPT(50),SEASON(12)
      COMMON JJ,KK,II,B,RMLOW,NAA,CLOW,NTRIB,NREA,NINIT,NJUNC,ELEV,
     *       DOLEV,TF,TEMP,CSAT,M,QUP,FINL,FINC,JA,IA,ICK,FINLN,DELQ,
     *       NI,NJ,K2,VEL,NSEAS,NRUN,TFN
      REAL   K2
      MAX=10
      ASUM=0.0
      TSUM=0.0
      VSUM=0.0
      HSUM=0.0

C                                          STEP-1
C                                          DIVIDE REACH INTO TEN (10) SUB-
C                                          REACHES AND CONSIDER EACH SUB-
C                                          REACH IN ORDER.
      DO 1 I=1,10
      Z=I

C                                          STEP-2
C                                          CALCULATE RIVER MILE AT
C                                          BEGINNING OF EACH SUBREACH.
      F(I)=G(5)-G(10)*Z/10.

C                                          STEP-3
C                                          CALCULATE FLOW ENTERING EACH
C                                          SUBREACH.
      DELQ=QUP+((G(2)-QUP)*Z/10.0)

C                                          STEP-4
C                                          CALCULATE VELOCITY AND TIME
C                                          OF TRAVEL IN EACH SUBREACH.
      VEL=DATA(IA,5)*(DELQ**DATA(IA,6))
      IF (DATA(IA,1)) 40,40,50
   40 VEL=0.0
   50 CONTINUE
      IF(VEL-.0001) 10,20,20
   10 G(3)=0.0
      GO TO 30
   20 G(3)=(DATA(IA,1)  /10.0)/(VEL*16.36)
   30 CONTINUE

C                                          STEP-5
C                                          CALL  K 2 C A L
      CALL K2CAL

C                                          STEP-6
C                                          CALCULATE FIRST TERMS OF THE
C                                          STREETER-PHELPS EQUATION.
      HSUM=HSUM+FINIS(IA,15)
      TEMPC=1.0159**(TEMP-20.0)
      G(4)=K2*TEMPC
      VSUM=VSUM+VEL
      TSUM=TSUM+G(3)
      XSUM=XSUM+G(4)
      G(4)=XSUM/Z

C                                          STEP-7
C                                          CALCULATE THE TERMS TO USE THE
C                                          EXPONENTIAL FUNCTION.
      IF(G(1),EQ,0.0) GO TO 5
      A=G(1)*G(6)/(G(4)-G(1))
      GO TO 6
    5 A = 0.0
    6 CONTINUE
      IF(G(11),EQ,0.0) GO TO 7
      AA=G(11)*G(12)/(G(4)-G(11))
      GO TO 8
    7 AA = 0.0
    8 CONTINUE
      TA=TSUM
      B=TA*(-G(1))

C                                          STEP-8
C                                          CALL  C H K P O
      CALL CHKPO
      DD=B
      B=TA*(-G(11))
      CALL CHKPO
      DN=B
      B=TA*(-G(4))
      CALL CHKPO
      DR=B

C                                          STEP-9
C                                          CALCULATE THE D.O. LEVEL IN
C                                          EACH SUBREACH USING THE
C                                          STREETER-PHELPS EQUATION.
      C(I)=A*(DR-DD)+AA*(DK-DN)+DR*(G(2)-G(9))+G(9)
      IF (G(I),LE.0.0) C(I) = 0.0
    1 CONTINUE
      AK2A=XSUM/10.0
      VELA=VSUM/10.0
      FINL=G(6)+DD
      FINLN=G(12)*DN
      FINC=C(10)

C                                          STEP-10
C                                          CALL  C M I N
      CALL CMIN
      IF(ICK)91,91,92
   91 V=G(6)
      Y=G(2)
      X=G(5)
      VV=G(12)
      XA=C(1)

C                                          STEP-11
C                                          WRITE INTERMEDIATE REACH
C                                          SUMMARY.
      WRITE (NJ,2) IA,X,Y,CLOW,RMLOW,XA,FINC,V,FINL,VV,FINLN
    2 FORMAT ( 7X,I3,4X,F7.1,2X,F7.1,2A,F5.2,3X,F7.1,5X,F5.2,4X,F5.2,
     *         3X,F6.2,3X,F6.2,3X,F6.2,3X,F6.2)

C                                          STEP-12
C                                          STORE REACH SUMMARY FOR
C                                          PRINTING IN FINAL SUMMARY.
   92 FINIS(IA,1)=IA
      FINIS(IA,2)=G(5)
      FINIS(IA,3)=G(10)
      FINIS(IA,4)=G(2)
      FINIS(IA,5)=CLOW
      FINIS(IA,6)=RMLOW
      FINIS(IA,7)=FINC
      FINIS(IA,8)=AK2A/TEMPC
      FINIS(IA,9)=ISUM
      FINIS(IA,10)=VELA
      FINIS(IA,11)=FINL
      FINIS(IA,12)=FINLN
      FINIS(IA,13)=HSUM/10.0
      FINIS(IA,14)=C(1)
      FINIS(IA,15)=G(6)
      FINIS(IA,16)=G(12)

C                                          STEP-13
C                                          RETURN TO CALLER (T R I B U).
      RETURN
      END
```

NOT REPRODUCIBLE

-SUBROUTINE CMIN-

```
      SUBROUTINE CMIN
      COMMON CRMIN(50),UNIT(20),F(10),C(11),IONE(20),G(15),TI LE(20),
     *       IORD(20,20),JUNC(20,3),INIT(10),IAUG(20),DOL(10) TRFAC(1 ),
     *       CONDZ(20,4),TEMMO(12),DATA(50,25),FINIS(50,16),CONDI(20,4),
     *       IDMCH(20,10),CONDE(20,4),IDENT(50,5),HWFLOW(10,.2),
     *       TRFACN(10),K2OPT(50),SEASON(12)
      COMMON JJ,KK,II,B,RMLOW,MAX,CLOW,NTRIB,NREA,NINIT,NJUNC,ELEV,
     *       DOLEV,TF,TEMP,CSAT,M,JUP,FINL,FINC,JA,IA,ICK,FIN N,DELQ,
     *       NI,NJ,K2,VEL,NSEAS,NRUN,TFN
      REAL  K2
      ITER=MAX-1
CCCCCC                                        STEP-1
CCCCCC                                        FIND SUBREACH WITH LO EST
CCCCCC                                        DISSOLVED OXYGEN LEVEL AND
C                                             RIVER MILE AT WHICH I  OCCURS.

      DO 1 I=1,ITER
      IF(C(I)-C(I+1))2,1,1
    2 C(I+1)=C(I)
      F(I+1)=F(I)
    1 CONTINUE
      RMLOW=F(MAX)
      IF (RMLOW.LE.0.0) RMLOW=0.0
      CLOW=C(MAX)
CCCCC                                         STEP-2
CCCCC                                         RETURN TO CALLER (D O E Q U).

      RETURN
      END
```

NOT REPRODUCIBLE

-SUBROUTINE K2CAL-

```
      SUBROUTINE K2CAL
      COMMON CRMIN(50),UNIT(20),F(10),C(11),IONE(20),G(15),TI LE(20),
     *       IORD(20,20),JUNC(20,3),INIT(10),IAUG(20),DOL(10) TRFAC(1 ),
     *       CONDZ(20,4),TEMMO(12),DATA(50,25),FINIS(50,16),CONDI(20, ),
     *       IDMCH(20,10),CONDE(20,4),IDENT(50,5),HWFLOW(10, 2),
     *       TRFACN(10),K2OPT(50),SEASON(12)
      COMMON JJ,KK,II,B,RMLOW,MAX,CLOW,NTRIB,NREA,NINIT,NJUNC,ELEV,
     *       DOLEV,TF,TEMP,CSAT,M,JUP,FINL,FINC,JA,IA,ICK,FIN N,DELQ,
     *       NI,NJ,K2,VEL,NSEAS,NRUN,TFN
      REAL  K2
CCCCCC                                        STEP-1
CCCCCC                                        CALCULATE THE REAERATION
CCCCCC                                        COEFFICIENT FROM VARIOUS USER
C                                             OPTIONS.

      H=DATA(IA,21)*(DELQ**DATA(IA,22))
      FINIS(IA,13)=H
      IOPT=K2OPT(IA)
      GO TO (1,2,3,4), IOPT
    1 K2=DATA(IA,15)
      GO TO 100
    2 K2=DATA(IA,16)*(VEL**DATA(IA,17))/(H**DATA(IA,18))*2.31
      GO TO 100
    3 K2=DATA(IA,19)*(G(2)**DATA(IA,20))*2.31
      GO TO 100
    4 K2=10.8*(1+((VEL/SQRT(32.17*H))**.5))*SQRT(DATA(IA,23)*.2.17/
     *     H)*2.31
  100 CONTINUE
CCCCC                                         STEP-2
CCCCC                                         RETURN TO CALLER (D O E Q U).

      RETURN
      END
```

VARIABLE DESCRIPTIONS

DOSAG-I

DESCRIPTION OF VARIABLES
IN COMMON

VARIABLE NAME		DEFINITION	UNITS
AMØNTH	=	Alphanumeric identifier for each month being simulated	-------
B	=	Reaeration rate coefficient multiplied by reach time of travel (negative)	-------
C(I)	=	Dissolved oxygen concentration in each subreach	mg/l
CLØW	=	Minimum dissolved oxygen concentration in a reach; recomputed for each reach	mg/l
CØNDE(JA,I)			
I=1		Dissolved oxygen concentration at end of reach JA	mg/l
I=2		Carbonaceous BOD concentration at end of reach JA	mg/l
I=3		Nitrogenous BOD concentration at end of reach JA	mg/l
I=4		Discharge at end of reach JA	cfs
CØNDI(JA,I)			
I=1		Dissolved oxygen concentration at beginning of reach JA	mg/l
I=2		Carbonaceous BOD concentration at beginning of reach JA	mg/l
I=3		Nitrogenous BOD concentration at beginning of reach JA	mg/l
I=4		Discharge at beginning of reach JA	cfs

VARIABLE NAME		DEFINITION	UNITS
CØNDZ(I,J)			
	J=1	Initial percent of dissolved oxygen saturation in headwater I	-------
	J=2	Initial carbonaceous BOD concentration in headwater I	mg/l
	J=3	Initial nitrogenous BOD concentration in headwater I	mg/l
	J=4	Initial discharge in headwater I	cfs
CRMIN(IA)	=	Minimum dissolved oxygen concentration for reach IA; stored for final summary	mg/l
CSAT	=	Saturation dissolved oxygen concentration at basin temperature and elevation	mg/l
DATA(I,J)			
	J=1	Length of reach I in miles	miles
	J=2	River mile to head of reach I	-------
	J=3	Value for carbonaceous reaction coefficient, K_1, for reach I (base e)	day^{-1}
	J=4	Value for nitrogenous reaction coefficient, K_3, for reach I (base e)	day^{-1}
	J=5	Coefficient of discharge to calculate velocity for reach I	-------
	J=6	Exponent of discharge to caluclate velocity for reach I	-------
	J=7	Discharge of incremental runoff for reach I	cfs
	J=8	Dissolved oxygen concentration of the incremental runoff for reach I	mg/l
	J=9	Carbonaceous B.O.D. of the incremental runoff for reach I	mg/l
	J=10	Nitrogenous B.O.D. of the incremental runoff for reach I	mg/l
	J=11	Discharge of sewage and industrial waste or withdrawal in reach I	cfs

VARIABLE NAME	DEFINITION	UNITS
J=12	Dissolved oxygen concentration of the sewage and industrial discharges in reach I	mg/l
J=13	Carbonaceous B.O.D. of the sewage and industrial discharges in reach I	mg/l
J=14	Nitrogenous B.O.D. of the sewage and industrial discharges in reach I	mg/l
J=15	Value for the reaeration coefficient, K_2, if option 1 for calculating K_2 is used (base e)	day-1
J=16	Coefficient of velocity if option 2 is used for calculating K_2	-------
J=17	Exponent of velocity if option 2 is used for calculating K_2	-------
J=18	Exponent of depth if option 2 is used to calculate K_2	-------
J=19	Coefficient of discharge if option 3 is used to calculate K_2	-------
J=20	Exponent of discharge if option 3 is used to calculate K_2	-------
J=21	Coefficient of discharge to calculate the average depth of water for reach I	-------
J=22	Exponent of discharge to calculate the average depth of water for reach I	-------
J=23	Slope of channel if option 4 is used to calculate K_2	-------

DELQ	=	Incremented discharge (runoff) used in subreach calculations	cfs
DØL(I)	=	Minimum permissable dissolved oxygen in basin (I = target level)	mg/l
DØLEV	=	Target dissolved oxygen concentration used in simulation run (one value per run)	mg/l
ELEV	=	Basin mean elevation	feet
FINC	=	Composite dissolved oxygen concentration entering downstream stretch	mg/l

VARIABLE NAME	DEFINITION	UNITS
FINIS(I,J)		
J=1	Reach I number	-------
J=2	River mile to head of reach I	-------
J=3	Length of reach I	miles
J=4	Total discharge leaving reach I	cfs
J=5	Minimum dissolved oxygen concentration in reach I	mg/l
J=6	River mile where minimum dissolved oxygen concentration occurs in reach I	-------
J=7	Dissolved oxygen concentration at the end of reach I	-------
J=8	Reaeration coefficient, K_2, value for reach I (base e)	-------
J=9	Time of travel for reach I	days
J=10	Mean velocity in reach I	fps
J=11	Carbonaceous B.O.D. at the end of reach I	mg/l
J=12	Nitrogenous B.O.D. at the end of reach I	mg/l
J=13	Depth of water in reach I	feet
J=14	Dissolved oxygen concentration at start of reach	-------
J=15	Carbonaceous B.O.D. concentration at start of reach	-------
J=16	Nitrogenous B.O.D. concentration at start of reach	-------
FINL	= Composite carbonaceous BOD entering the downstream stretch	mg/l
FINLN	= Composite nitrogenous BOD entering the downstream stretch	mg/l

VARIABLE NAME		DEFINITION	UNITS
G(K)			
	K=1	Carbonaceous bio-oxidation rate adjusted for temperature	1/day
	K=2	Total flow entering a reach	cfs
	K=3	Total time of travel through a reach	days
	K=4	Reaeration coefficient adjusted for temperature	1/day
	K=5	River mile at head of reach	miles
	K=6	Composite carbonaceous BOD for a reach	-------
	K=7	Mean monthly temperature	Deg. Cent.
	K=8	Composite dissolved oxygen for a reach	-------
	K=9	Dissolved oxygen saturation concentration at mean monthly temperature	mg/l
	K=10	Length of reach	miles
	K=11	Nitrogenous bio-oxidation rate adjusted for temperature	1/day
	K=12	Composite nitrogenous BOD for a reach	-------
HWFLØW	=	Headwater flow	cfs
IA	=	Reach identification subscript	-------
IAUG(I)	=	Headwater stretches where water for augmentation is available	-------
ICK	=	Flag for print option 1=Final summary 0=Intermediate and final summaries	-------
IDMCH(JA,I)	=	Flag to indicate number of augmentation sources upstream form stretch JA	-------
II	=	Junction identifier for flow augmentation	-------
INIT(I)	=	Headwater stretch identifier	-------

VARIABLE NAME		DEFINITION	UNITS
IØNE(KK)	=	Flag used in finding headwater stretches with augmentation availability	-------
IØRD(I,J)	=	Identifier for order of reaches in each stretch	-------
JA	=	Stretch subscript	-------
JJ	=	Junction identifier for flow augmentation	-------
JNIT(I)	=	Headwater identifier for flow augmentation calculations	-------
JUNC(I,J)	=	Junction identification; identifies upstream and downstream stretches entering junction	-------
KK	=	Junction identifier for flow augmentation	-------
K2	=	Reaeration coefficient for reach computations	1/day
K2ØPT(I)	=	Option for calculating reaeration coefficient for reach I	-------
M	=	Flag to indicate end of computations for a stretch	-------
MAX	=	Counter for subreaches within a reach	-------
NI	=	Identifier for computer input device	-------
NINIT	=	Number of headwater reaches in the basin	-------
NJ	=	Identifier for computer output device	-------
NJUNC	=	Number of junctions in the basin	-------
NREA	=	Total number of reaches in the basin	-------
NRUN	=	Counter for number of complete dissolved oxygen profiles calculated	-------
NSEAS	=	Number of each month of the water year (e.g. October = 1)	-------

VARIABLE NAME		DEFINITION	UNITS
NTRIB	=	Total number of stretches in the basin	-------
N2ØPT	=	Plotting option 0 ≡ No plot 1 ≡ Plot of DO and BOD	-------
QUP	=	Total upstream flow entering a reach	cfs
RIDENT(I,J)	=	Reach identification, alphanumeric	-------
RMLØW	=	Location of minimum dissolved oxygen concentration in a reach	river mile
SEASØN(NSEA)	=	Month for which dissolved oxygen calculations are being performed	-------
TEMMØ(I)	=	Monthly mean stream temperatures	Deg. Cent.
TEMP	=	Temperature for which dissolved oxygen calculations are performed	-------
TF	=	Waste treatment factor (carbonaceous) for a specific computational run	-------
TFN	=	Waste treatment factor (nitrogenous) for a specific computational run	-------
TITLE(I)	=	Basin title, alphanumeric	-------
TRFAC(I)	=	Treatment factor for carbonaceous wastes (maximum of 5)	percent
TRFACN(I)	=	Treatment factor for nitrogenous wastes (maximum of 5)	percent
VEL	=	Velocity of flow in a reach	feet/sec.

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